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TO

PHYSIOLOGY

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PREFACE.

These Aids to Physiology are intended to assist students to put together the knowledge they have already acquired by attending a course of lectures on the subject, or from the perusal of some of the well-known text-books.

The author thinks that the short descriptions of the structure and functions of the different organs will be easily comprehended by all students who have mastered Huxley's 'Elements'; but the student must not expect to acquire a sufficient knowledge of physiology from so short an epitome of the subject as the present little book affords.

ADDENDA.

Page 6, line 2 from the bottom, *after* 'element,' *read* 'except the salts of carbonic acid.'

Page 23.—*Diastole* of the ventricle of the heart means dilatation of the cavity by the influx of blood. *Systole* means contraction of the cavity by the action of its muscular walls.

AIDS TO PHYSIOLOGY.

I.—INTRODUCTORY.

PHYSIOLOGY is the science which treats of the phenomena of life; Vegetable Physiology relates to the life of plants, Animal Physiology to that of animals, and Human Physiology to that of man.

The term life includes all the phenomena exhibited by a living creature.

There is nothing more difficult than to give an exact definition of life, but we know that anything is alive if it moves spontaneously, feeds, and, as a consequence, grows, and multiplies. Everything that is alive does all this at some time or other.

The movement of living things is of two kinds; the movement of their parts as they grow, and the more obvious movements which they make for the capture of food and for their general safety.

The former kind of movement is common to both animals and plants. The latter kind is rare in plants. It is seen in the sensitive plant, which closes its leaves when they are touched, and in 'Venus' fly-trap,' which closes its leaves suddenly when a fly rests upon them, and crushes the insect, upon which it feeds.

Life may be latent, as in a seed, but the cells of the seed grow, move, and feed as soon as the seed is subjected to the conditions necessary for the development of its powers. A dead seed will do none of these things, under any conditions.

The actions of an animal or plant, or of a part of one, are called its functions. Growth and multiplication, which are common to both animals and plants, are called Vegetative Functions; sensation and movement are spoken of as Animal Functions.

Most animals are complex in structure, and consist of parts having different functions; these parts are called Organs; and the whole animal is an Organism.

Some of the lower animals have no distinct organs, but consist of one kind of material; this looks like jelly, but it feeds, grows, and moves; it has no definite shape, and is very soft.

This substance is called Protoplasm, from *protos*, first, and *plasma*, a material which can be moulded, as a potter moulds clay. This substance is found as a part of every animal and plant.

Protoplasm has a very complex chemical composition. It consists of Oxygen, Hydrogen, Nitrogen, and Carbon, with a little Sulphur or Phosphorus.

During its growth it undergoes numerous chemical changes, and a great variety of compounds are formed. Some of these contain Nitrogen, like the Protoplasm itself; others contain none. They all, however, contain Carbon.

These substances, and all the substances which can be prepared from them by chemists, are called Organic substances.

It was formerly supposed that organic compounds could not be prepared except by the agency of life; but it is now known that many can be prepared directly from inorganic substances. Chemists call all carbon compounds, which contain more than one other element, *organic*. *Every* other chemical substance is inorganic.

An animal may be justly compared to a machine, to a certain extent, and of all artificial machines to a steam-engine. When a steam-engine works, two things are necessary, always presuming the mechanism is in order: first, a supply of fuel; and secondly, a supply of air.

In the case of an animal, the food represents the fuel, and the breathing of the animal is the means by which air is taken in. The effect of the air taken in is the slow combustion of a portion of the food; and just as the burning of the coal supplies the motor-power of the engine, so the burning of the carbon and hydrogen of the food supplies the motor-power to the animal.

In the case of the engine, the fire must be lighted; and in the case of the animal, it must be alive. The engine gets out of order by working, and it cannot repair itself; the animal gets out of order by working, or rather tends to do so, but it does repair itself—it is a self-repairing mechanism. So the engine has to be adjusted to do some special kind of work; the animal adjusts itself to many functions—it is a self-adjusting mechanism. No other form of machine is either self-repairing or self-adjusting; therefore it does not appear, to the author, that the animal exhibits as many points of similarity, as differences, when compared to an artificial machine.

The textures out of which the body is built are called tissues. These are divided into two great classes:—

1. The Connective Tissues, which form the supporting framework of the body.
2. The Active Tissues, by which its functions are performed.

In the former group are the Bones, Cartilages, Tendons, the Elastic and Areolar Tissues, and the Dermis of the Skin; in the latter, the Muscles, the Epithelia, Nervous Tissues, the Endothelia, and the Blood.

All the exposed surfaces of the body, both inside and out, are covered with one or more layers of cells; these are called Epithelia. The various closed cavities are lined with cells which are called Endothelia.

In a very young state every part of an animal consists entirely of protoplasm, in minute spherical masses. These masses are called Cells; they are so called because the older physiologists only knew of them when they had become altered by growth.

As a rule they become altered in the following manner: First they get a minute central harder particle, called a Nucleus—the nucleus generally contains one or two minute bright-looking globules, called Nucleoli; next the cell is seen to contain numerous minute globules around the nucleus—these coalesce and form a drop of fluid; this is called the Cell Contents. The protoplasm then forms a wall, the Cell Wall, around the contents and nucleus. The wall usually becomes thickened and hardened, and so supports and protects the contents.

All the parts of an animal consist, at first, of cells. Some of these become lengthened into fibres; some remain soft, and without any wall; others develop a wall; these changes of the cells are spoken of as Differentiation.

The first cell of every animal is the Ovum, and the first stage of development consists in the division and subdivision of the ovum, so that a small cellular mass results. This mass of cells afterwards becomes a hollow vesicle surrounded by a cellular wall called the Blastoderm.

The blastoderm soon divides into three layers, or envelopes. The outer is called the Epiblast, the middle *the Mesoblast,* and the inner the Hypoblast. The cells of these three layers become differentiated to serve different functions.

The cells of the outer layer form the Epithelium, or cellular covering of the body, all the different sensory structures by which we feel, see, hear, and are generally able to perceive external impressions, and the central nervous system. The middle layer forms all the muscles, bones, blood vessels, and tissues generally; and the internal layer becomes the epithelial lining of the alimentary canal and respiratory passages.

The tissues formed from the outer and inner layers always remain cellular, and are the epithelia, except those of the central nervous system—these are called Nerve Corpuscles.

Epithelial Cells are of four kinds :—

1. Squamous or Tesselated Epithelium—thin flat cells, usually arranged in numerous layers. Tesselated Epithelium covers the whole surface of the body, where it is called Epidermis; it also lines the cavity of the mouth, the pharynx and the œsophagus, as far as the cardiac extremity of the stomach. It lines the urinary bladder and the vagina. Tesselated Epithelium also exists in a single layer in the anterior chamber of the eye, and in the smallest bronchi, as well as in the air cells of the lungs.
2. Columnar Epithelium—consists of a single layer of columnar cells; it is found in the alimentary canal, from the cardiac extremity of the stomach to the anus. It also lines the ducts of most glands.
3. Ciliated Epithelium—consists of cells covered on their free surface with minute hair-like processes, which are in continual vibration

during life, sweeping the fluid, which is secreted by the membranes on which they are found, in a definite direction. It is found in the respiratory passages, *i.e.*, the inferior and the lower half of the middle meatus of the nose, the interior of the larynx, the trachea, and those bronchi which are more than $\frac{1}{40}$ of an inch in diameter. It is also found in the vasa efferentia of the testis of the male, and in the epididymis as far as its lower end. In the female, in the uterus, from the middle of the cervix to the fimbriated extremities of the Fallopian Tubes.

4. Spheroidal or Glandular Epithelium—the epithelial cells which line the acini of glands. These cells are more or less polygonal, from mutual pressure, and they form the various secretions of the different glands.

The epithelial cells are protective. They resist the absorption of various substances, as animal poisons; in the alimentary canal they take up nutrient matter, and appear to exercise a selective absorption.

They form sensory surfaces, and in glands prepare the various secretions and excretions of the body.

Nerve Cells will be described hereafter.

The other tissues are all derived from the Mesoblast.

A. The Connective Tissues:—

(*a*) Areolar Tissue, or, as it is often called, Connective Tissue, consists of a loose network of fibres. These fibres are of two kinds; white bands which are wavy, and longitudinally striated. When boiled, they dissolve, and become converted into Gelatin.

These form the greater part of the areolar tissue, but they are intermixed with a few elastic fibres of a yellow colour, which are unaffected by boiling. These are spoken of as Yellow Elastic Fibres. They consist of a very indestructible substance called Elastin.

Elastic Fibres exist without any white fibres in the vocal cords, the ligamenta subflava of the vertebræ in man, and in the ligamentum nuchæ of animals; they are very abundant in the tissue of the trachea and bronchi, as well as in the lungs.

Elastic fibres are also found in a variety of cartilage—yellow elastic cartilage. The elastic coats of the blood-vessels consist of plates of elastin.

White fibrous tissue, which forms the tendons and ligaments, as well as the serous membranes, differs but little from the wavy bands of areolar tissue. Its fibres are, however, straight; they are parallel with each other in tendons and ligaments, but cross and recross in every direction in the serous membranes, and in the periosteum of bone.

The true skin, the *corium*, and the mucous membranes, consist of condensed areolar tissue, so dense at the surface as to appear nearly structureless; but quite loose, and continuous with the subcutaneous, or submucous, connective tissue below.

(*b*) Cartilage and bone consist of a matrix with numerous cells imbedded in it. The matrix yields a substance, when boiled, closely allied to gelatin.

In cartilage the whole matrix consists of animal matter, dissolves entirely by boiling, and is converted into a gelatinous substance called Chondrin

Anatomically there are four kinds of cartilage:

(1) Cellular Cartilage, in which the whole substance of the tissue is made up of polygonal cells, the matrix merely forming a thin layer of cementing material between the cells. It is not found in man, except in the very rudimentary embryo, where it forms the notochord.

(2) Hyaline Cartilage has the matrix in which the cells are imbedded, of structureless or slightly granular material. Hyaline cartilage is either permanent or temporary. Temporary cartilage becomes converted into bone; permanent cartilage persists through life as cartilage. The permanent cartilages are the articular cartilages of bone, the costal cartilages, and the cartilages of the larynx and the nose.

(3) White Fibro-Cartilage has a matrix converted in part into white fibrous tissue. The white fibro-cartilages are the inter-articular cartilages, the cotyloid and glenoid ligaments, and the small cartilages which occur in the substance of some tendons.

(4) Yellow Fibro-Cartilage has the matrix permeated in every direction by branching yellow fibres of elastin. It forms the tarsal cartilages of the eyelids, the Eustachian tube, the cartilage of the external ear, the cartilages of Wrisberg, the cornicula of the larynx, and the epiglottis. Both white and yellow fibro-cartilage are permanent.

The uses of cartilage are: to keep open the air-passages; to serve as a matrix for the development of bone; to form the elastic parts of the skeleton; and to break shocks by forming buffers in the joints.

The intervertebral substance is sometimes spoken of as white fibro-cartilage, but it is a special structure, formed of white fibrous tissue, and contains very little cartilage.

(*c*) Bone.—In bone, only one-third of the matrix consists of animal matter; the rest, of earthy salts, chiefly basic phosphate of lime. The cells of bone are much smaller than those of cartilage. They lie in spaces in the matrix, called Lacunæ, and send numerous fine branching processes throughout the matrix, which connect them with each other. The canals in which these processes lie are called Canaliculi. Bone is vascular, and cartilage is not, or is only slightly vascular. The vessels of bone run in canals called Haversian Canals.

The tissue of bone is either compact or cancellous. In the compact bone the arrangement of the Haversian canals is very regular, and the lacunæ are arranged in laminæ, forming cylinders around the Haversian canals. The cancellous bone is formed of thin plates forming a spongy tissue; there are either no Haversian canals in these plates, or very few, and the lacunæ are arranged in laminæ parallel with the surfaces of the plates.*

All the bones of the body, except those of the roof of the skull and the face, and perhaps the clavicle, are formed from cartilage. The cartilage first becomes vascular, then the cartilage cells are removed and replaced by bone corpuscles, from which the bone matrix is developed, probably as an exudation.

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* For marrow and adipose tissue, see ductless glands and skin

The cartilage is converted into bone gradually, the change commencing at a point in the centre of the cartilage; this spot is called a Centre of Ossification. The cartilage cells around a centre of ossification are arranged in radiating lines.

The bones which are not formed in cartilage are developed in connective tissue; a number of bone cells are found in the meshes of this tissue, and the bone matrix is formed by these. Such bones are said to be developed in membrane.

B. The active tissues :—

Muscle fibres are of two kinds; non-striated and striated. Non-striated muscle consists of elongated, fusiform cells, is pale in colour, and forms the muscular portion of the viscera and blood vessels.

Striated muscle is red in colour; it consists of fibres; each fibre having a structureless sheath, the Myolemma. The sheath contains a semi-fluid protoplasm, seen to be marked with alternate dark and bright lines, when examined with a high power of the microscope. After death the contents of the muscle sheath become longitudinally fibrous, and the individual fibres, which then fill the tube, are called fibrillæ.

The majority of the striated muscles are under the control of the will; they are, therefore, called Voluntary Muscles. The non-striated muscles are never under the control of the will; they are called Involuntary Muscles.

The muscle fibres of the heart, the blood (which may be regarded as a fluid tissue), the nervous tissues, glands, and endothelium, will be described in different portions of the book, in connection with the physiology of the parts.

The student is earnestly recommended to study the tissues, for himself, with the microscope, as there is no other way of learning them. The above notes are only intended as a means of putting together knowledge already acquired, by pointing out a few of the most important facts, some of which he may not feel able to classify in his mind sufficiently well to write a good paper at an examination. They are only intended as aids; and he must not rest content with the very small amount of information for which the author has space in these pages.

The functions of animals are classified in the following manner:—

1. Vegetative Functions, common to both animals and plants:
   - (*a*) Nutrition.—The manner in which the food is changed into the substance of the animal, or into some substance capable of forming the material which is consumed in moving the animal.
   - (*b*) Respiration.—The manner in which air is taken in, and the products of combustion are eliminated from the body.

- (*c*) Excretion.—The manner in which other forms of waste material are eliminated.
- (*d*) Secretion.—The manner in which the different chemical substances are prepared for use in the body; the fluids, for instance, which digest the food.
- (*e*) Reproduction and development. — The manner in which the young are formed and developed.

2. The Animal Functions.—The manner in which the animal adjusts itself to the various conditions under which it is placed; its sensations and movements.
   - (*a*) The actions of the nervous system, by which the animal feels and initiates movements.
   - (*b*) The action of the muscular system, by which the movements of the animal are effected under the guidance of the nervous system.

All complicated animals, which have different organs for different purposes, require a highway by which the various substances may be transferred from one part of the body to another. This is effected by the blood, which is contained in a system of vessels, and is moved by the action of the heart. This constitutes the function of the circulation.

As all the actions of the body depend on the circulation, it will be considered first.

II.—The Blood.

The blood is entirely contained in the heart and blood vessels,—the arteries, capillaries, and veins.

The only exception to this is, according to some authorities, that the arterioles of the spleen open into lacunæ, or spaces between the trabeculæ, so that the blood is not contained in capillaries between the arterioles and small veins of this organ.

The blood is a thick viscid fluid, opaque in even the thinnest layers. When examined by the microscope, it is seen to consist of a vast number of very pale yellow discs, suspended in a colourless fluid.

The discs, when seen in numbers, are red, and give the blood its characteristic colour. They are called Red Blood Corpuscles. The fluid in which they are suspended is called the Liquor Sanguinis; it has a pale straw colour when separated from the corpuscles.

The colour of the blood depends on that of the corpuscles; it varies according to the vessel from which it is taken. That from an artery is bright scarlet, that from a vein is of a dark purple; hence, bright blood is called Arterial, and dark blood is called Venous.

Whether the blood is taken from an artery or vein, it becomes solid a few minutes after it is drawn: it is said to Coagulate, or Clot. The surface of the clot soon becomes of a bright scarlet colour if it is exposed to the air, and the interior becomes so dark that it looks almost black. If it be cut into, the cut surface becomes rapidly scarlet. This is due to the absorption of oxygen from the air.

The changes of colour in the blood are entirely due to the oxidisation and deoxidisation of a substance contained in the red blood corpuscles—Hæmoglobin. This substance has a strong affinity for oxygen, and absorbs it with great readiness.

The cause of the interior of the blood clot becoming dark, is that it contains other substances which take oxygen from hæmoglobin, although they cannot take oxygen directly from the air. This is accounted for by the theory that the hæmoglobin converts the oxygen into ozone. The substances which deoxidise the hæmoglobin are such as are burnt in the body during life.

Oxidised blood is always bright, and deoxidised blood is always dark.

The red blood corpuscles are $\frac{1}{3600}$ of an inch, or eight micromillimètres in diameter—a micromillimètre is a thousandth part of a millimètre. They are $\frac{1}{10,000}$ of an inch, or two micromillimètres, thick.

They are composed of a sponge-like substance called the Stroma, dense near the surface and loose in their interior. The stroma is permeated by a coloured fluid, the hæmoglobin. The stroma is so dense near the surface of the corpuscle, that it acts like a cell wall.

The blood discs are naturally biconcave; but when the blood is diluted with water, they swell up and become biconvex; the addition of a salt to the blood renders them more strongly biconcave.

The hæmoglobin soon dissolves out of the blood corpuscle, if the blood is diluted with water. When this happens, the blood becomes transparent; it is then called Laky Blood, from its colour.

In the case of human blood, the hæmoglobin decomposes very rapidly, and becomes converted into two substances called Globulin and Hæmatin: if the blood is kept at a freezing temperature, this does not happen, and the hæmoglobin crystallises in prismatic plates. These are called Blood Crystals.

In healthy human blood there are on an average five million corpuscles in a cubic millimètre of blood—a small drop. In some forms of anæmia, the number is *reduced to* less than a million.

The red corpuscles have a higher specific gravity (1088) than the liquor sanguinis (1020), so that they sink in it, if it clots slowly. They are not nucleated in man or mammals, but in other vertebrates they are nucleated like a cell.

Their function is to carry oxygen from the lungs to every part of the body. In the capillaries they yield the oxygen up to the tissues; just as in the interior of the blood clot, they yield it to oxidisable compounds.

There are, also, cells in the blood called White Corpuscles. These have a distinct nucleus, but no cell wall. When the blood is drawn they assume a spherical form, and measure $\frac{1}{2500}$ of an inch in diameter; but when they are alive they are shapeless, and exhibit very active movements. These are spoken of as Amœbiform, because they resemble the movements of a minute structureless animalcule called an amœba.

The movements of a white corpuscle consist in putting out and drawing in finger-like processes from its surface. The corpuscles consist of protoplasm. In health there are two or three white corpuscles to every thousand red ones; the number is somewhat increased a few hours after a meal.

They are probably concerned in the nutrition of the blood, and are perhaps converted into red corpuscles by the nucleus becoming coloured, and the disappearance of the protoplasm surrounding it.

The coagulation or clotting of the blood is due to a change in the liquor sanguinis. This consists in the formation of a network of a fine fibrous material called Fibrine. The fibrine entangles the fluid and corpuscles in its meshes, and afterwards contracts and squeezes the fluid out, so that the clot soon floats in fluid.

This fluid is not the same as liquor sanguinis, as the fibrine has been formed from the liquor sanguinis. It is called Serum. It is not believed that there is any fibrine in liquor sanguinis, but there are two substances called Fibrinogen and Fibrino-plastin; these unite to form fibrine.

There is reason to believe that this union is due to the presence of a substance analogous to a ferment, formed by some change in the white blood corpuscles.

Blood does not clot in the body, except when the blood vessels are injured: white blood corpuscles then accumulate in great numbers at the injured spot, and a clot is formed. The use of this clot is to prevent hæmorrhage from the injured vessels.

Blood which escapes into cavities in the body does not generally clot, but remains fluid.

When blood is drawn from the body into a kind of test tube made of a piece of healthy blood vessel, it will not clot, even when exposed to the air, unless some foreign body, as dust, falls into it. Blood always clots when it comes into contact with any inorganic surface, and generally the surface with which the blood is in contact must be covered with cells, or the blood will clot.

The blood does not clot in the body after death, except under exceptional circumstances. It sometimes forms colourless clots in the heart and great arteries, immediately before death, and coloured clots form round the colourless ones, after death.

Before the blood clots, there is a tendency for the red corpuscles to adhere together by their flat surfaces, like piles of coins. These piles are called Rouleaux.

The result of this is that the red corpuscles sink more rapidly than they otherwise would; at the same time *the white corpuscles* rise to the surface; hence there is a tendency for the clot to consist of two layers—an upper white and a lower red stratum. The white layer is very thin, and in normal human blood it is not perceptible, as the process of clotting is so rapid that the red corpuscles have no time to sink.

In blood drawn in inflammatory diseases the clotting is much slower, and the surface of the clot is covered by a white layer, the Buffy Coat. A buffy coat is also formed in some other conditions, when the white corpuscles are very numerous, and the red ones sink too quickly, as in anæmia.

The blood, and perhaps the liquor sanguinis, contains all the different substances required for the nourishment of the body. The principal of these is albumen.

The serum, after the formation of the clot, contains so much albumen that it becomes as solid as the white of an egg when it is heated to a temperature of 73° Cent.

Beside albumen and the constituents from which fibrin is formed, the liquor sanguinis contains salts of various kinds, chiefly chloride of sodium, phosphates of lime and magnesia, and carbonates and sulphates of soda and potash. The potash of the blood, however, is chiefly contained in the blood corpuscles. The alkaline carbonates predominate in the blood, so that it has an alkaline reaction. This alkalinity is connected with the solution of the albumen.

Beside the substances named, there are others in much smaller quantity. These are called Extractives. Some are undoubtedly on their way out of the body, as urea and kreatin, and result from the wear of the organism ; others, as sugars and fats, are probably concerned in the production of animal heat and movement.

One of the most remarkable facts connected with the blood is, that whatever we may eat or drink, it remains nearly constant in quantity and quality. In health it constitutes one thirteenth of the weight of the body. Its specific gravity is 1035. About two-thirds of the weight of the blood consist of red corpuscles, and one-third of liquor sanguinis.

When the corpuscles from a thousand grains of blood are dried they weigh 130 grains; the dry albumen 70, the salts and extractives about 15 grains.

III.—THE HEART AND BLOOD VESSELS AND THE CIRCULATION.

The heart is a double organ, consisting of two auricles and two ventricles—an auricle and a ventricle on the right, and an auricle and a ventricle on the left side. These pairs of cavities are very similar on the two sides. The right pair contain venous, and the left pair arterial blood.

In the fœtus the right and left auricle communicate through the foramen ovale, but this closes soon after birth, and then the only communication between the two sides of the heart is through an entire set of blood vessels.

Starting from the right auricle, the blood has the following course: it passes through the tricuspid valve into the right ventricle; from the right ventricle it is distributed to the lungs through the pulmonary artery. In the lungs the blood is oxidised, and returns to the left side of the heart by the pulmonary veins, which open into the left auricle. This is called the Lesser or Pulmonary Circulation. It must be observed that the blood in the pulmonary artery is venous, and in the pulmonary vein is arterial.

From the left auricle it passes through the mitral valve into the left ventricle; from the left ventricle it passes into the aorta, which distributes it to the whole body. In the capillaries of the system the blood gives up its oxygen and becomes venous; it then passes into the veins and back to the right auricle. This is called the Greater or Systemic Circulation.

Beside the valves between the auricles and ventricles, there are three valves at the orifice of the pulmonary artery, and three at the orifice of the aorta. These are called Semilunar, from their shape. There are also valves in the veins of the system, wherever these are subjected to intermittent pressure from muscular action.

The movement or circulation of the blood is caused by the action of the heart. The auricles contract suddenly, and force the blood which they contain into the ventricles. The whole contraction of the auricle takes less than the eighth part of a second.

The blood is prevented from passing back into the great veins by the manner in which the contraction of the auricles takes place; it commences at the orifices of the great veins, and sweeps the blood, as it were, into the ventricles. The ventricles then contract, comparatively slowly; the whole time of the contraction occupying about four or five tenths of a second. At the commencement of the contraction of the ventricles the blood gets behind the auriculo-ventricular valves, and closes them, so that no blood passes back into the auricles. The ventricles empty themselves, the right into the pulmonary artery, and the left into the aorta.

The force required to propel the blood through the systemic circulation is about three times as great as that required to send it through the lungs: so the wall of the left ventricle is about three times as thick as that of the right. The two auricles contract at the same time, and the two ventricles also contract at the same time; that is, the auricles and ventricles contract synchronously.

Each pulsation of the heart is accompanied by two sounds. These are distinctly heard when the ear is applied to the chest—immediate auscultation—or by means of a stethoscope—mediate auscultation. They are well described by the syllables *lūb dŭp;* then follows a pause, during which no sound is heard; this lasts nearly the same time as the two sounds, and then the sounds are repeated. The long sound, *lūb*, is called the First Sound—it is heard during the contraction of the ventricles; the Second Sound, *dŭp*, is heard at the end of the contraction of the ventricles, during the closure of the valves at the mouths of the great arteries.

The first sound is ascribed by different authorities to one or all the following causes: the contraction of the walls of the ventricles, the closure of the auriculo-ventricular valves, and the rush of blood through the aortic orifice. The second sound is ascribed to the closure of the aortic valves, and to the vibration of the blood in the aorta, from the sudden stoppage of the stream from the heart.

Synchronously with the first sound, the apex of the heart strikes against the wall of the chest, in the fifth intercostal space, about an inch inside a line drawn downwards through the left nipple: this is the Impulse. The force of the impulse varies with the position of the body. It is stronger in the prone than in the supine, or in the upright position; it is also stronger during expiration than during inspiration.

The heart, in the healthy human adult, makes about 75 pulsations in a minute; at birth it makes 140, at three years 100, and in old age only about 60 or less. In children and women the number of pulsations varies more than in men, and the heart beats more rapidly in women than in men.

The rule throughout, in warm-blooded animals, is that the smaller and the more active the animal, the more rapid the pulsations of the heart. This rule applies to the human being at different ages.

The rate of the heart's action increases slightly again in extreme old age.

The pulse at the wrist is nearly synchronous with the first sound of the heart. It takes a perceptible, but very short time for the arterial pulse to travel from the heart to the peripheral arteries.

The pulse is caused by a sudden increased distension of the vessel, which is already distended, from the increased blood-pressure due to the contraction of the ventricle. The arteries are increased both in diameter and length by this means.

The pulse is a wave in the artery—it can be accurately observed by the Sphygmograph. The wave travels at the rate of about thirty feet a second.

Sometimes the pulse appears to be double—Dicrotic. Dicrotism is usually due to a relaxed condition of the muscular coat of the arteries.

The arteries lead from the heart. They are thick-walled vessels, which do not collapse when they are cut. They contract and empty themselves in the body after death, so that all the blood is found in the capillaries and veins. The name artery means air-tube, and was given to them, from this circumstance, before the circulation of the blood was understood.

The veins lead to the heart. They are thin-walled vessels, which collapse when they are cut. The aggregate capacity of the veins is about three times that of the arteries.

Both arteries and veins have three coats.

The outer of these is a connective-tissue coat; it is called the Tunica Adventitia. It is chiefly developed in the largest arteries. In these it serves the same purpose that the net does over the india-rubber ball of a spray apparatus—it prevents the artery from being too much stretched when the heart fills it with blood.

The middle coat is composed partly of plates of yellow elastic tissue, and partly of non-striated muscle fibres. It is called the Tunica Propria. In the large arteries the middle coat is almost entirely elastic, and in the small ones almost entirely muscular; in moderate-sized arteries, like the radial and ulnar, it is partly muscular and partly elastic.

The functions of the middle coat are to keep up a continuous pressure on the blood, and to regulate the amount of blood sent to each organ. The first function is performed by the elastic tissue, the second by the muscle fibres.

As the largest arteries must take all the blood sent to them by the heart, they do not need to regulate the supply. This is done by the heart.

The quantity of blood sent to the different organs at different times, is regulated by the muscular coats of the vessels which supply them. The condition of the muscular coat is regulated by the sympathetic nerves.

The elastic coat of the arteries is always more or less distended. The pressure which it exerts on the blood is the cause of the blood-pressure, and of the peculiar characteristics of arterial hæmorrhage. It keeps the blood continuously flowing through the capillaries in the intervals between the successive contractions of the ventricles. The blood-pressure is highest immediately after the contraction of the left ventricle; it becomes gradually less until the commencement of the next contraction.

The blood-pressure has been measured in the aorta of various animals by joining the cut carotid to a U-shaped tube, one limb of which contains mercury. Such a tube is called a Manometer.

The blood-pressure in the aorta has been calculated, in man, to be equal to from eight to twelve inches of *mercury.*

The blood-pressure in the arteries is maintained by the contractions of the ventricle, and is expended in forcing the blood through the capillaries. The causes of the variations in the blood-pressure are the force and number of the contractions of the ventricle, the quantity of blood sent into the vessel by each contraction, and the size of the capillaries.

The application of cold to the skin, by contracting the capillaries, raises the blood pressure in the arteries. A warm bath, by dilating the capillaries of the skin, lowers the blood pressure. Exercise, by accelerating the heart's action, tends to raise the blood-pressure; but it does not do so in health, as the size of the capillaries is regulated by the nerves of the blood-vessels, and the nerve centres in the medulla, so that the arteries do not get over-distended.

The third coat of an artery is called the Tunica Intima; it consists, in the large arteries, of a tube of elastic tissue and in the small ones of a structureless membrane, lined by a layer of smooth cells. These cells are called Endothelial Cells, to distinguish them from epithelial cells.

In both arteries and veins the internal coat is impervious to blood, so that the outer and middle coats of the vessel have small blood-vessels called Vasa Vasorum. These ramify in the outer coat and dip into the middle coat with the nervi vasorum, which supply its muscular fibres.

The largest arteries have often a sheath of connective tissue outside the tunica adventitia. This is the sheath of the artery. It is opened to tie the artery.

When a vessel is tied, the two inner coats should be ruptured by the ligature, the outer coat remaining intact. This is easily done, as the elastic tissue is always brittle; it favours the formation and subsequent organisation of the clot, and the permanent closure of the artery.

As the arteries ramify, the diameter of each becomes less, but the united sectional area of the branches becomes greater. Hence the blood flows more slowly in the small branches than in the larger ones.

The mean rate of the flow of blood in the aorta of man, is about twelve inches per second; in the capillaries it is no more than $\frac{1}{30}$ of an inch; that is, the blood goes 360 times as fast in the aorta as in the capillaries.

The aggregate cross section of all the capillaries is to that of the aorta as 1 to 360, or nearly as a day to a year.

The whole time it takes for any given blood corpuscle to pass through the entire circulation from the heart and back is, in round numbers, about half a minute. The distance traversed in the capillaries is very short, probably less than $\frac{1}{100}$ of an inch.

The capillaries are about $\frac{1}{3000}$ of an inch in diameter, and are composed of a single layer of very thin fusiform cells, dovetailed together, as it were, by serrations.

Exchanges take place between the blood and the tissues through the capillary walls, both of oxygen and carbonic acid, and of nutrient material: the white blood corpuscles have also been seen to pass through the capillary wall. This probably takes place constantly in inflammation.

The circulation can be seen with the microscope in the capillaries of the transparent web of a frog's foot. The white blood corpuscles travel close to the walls of the vessels, and appear to lag behind the red ones, as if they adhered to the wall of the vessel.

The capillaries form a close net-work in all the vascular tissues. This net-work is closest in the lungs, in glands, and in the mucous membrane of the small intestine. It is widest in the connective tissues which *have no work to perform.*

The size of the capillaries undergoes considerable change in a part. They are largest when it is functionally active. Their size depends entirely on the size of the arteries supplying them at the time, as they have no contractile coat, like the small arteries. These changes are entirely passive.

Veins differ from the corresponding arteries in being about three times as large, and in having thinner coats, which contain a very large quantity of white fibrous tissue; hence they are tougher and less elastic. All those which are subject to intermittent pressure have valves; these have but one flap in the smaller veins, and two in the larger.

The veins serve not only to conduct the blood back to the heart, but the systemic veins are a kind of store place for surplus blood; they are so large that they will hold all the arterial blood, as well as their own. This is seen in the dead body. In death by suffocation the blood is not able to pass through the lungs, and the heart pumps all the blood it contains in its left side through the arteries into the veins; hence the great venous congestion and distention of the right side of the heart observed after death in this manner.

The veins of the abdomen are so large, that syncope may be produced, by the sudden dilatation of the arteries, permitting the flow of blood into the abdominal veins too suddenly, as surely as by blood-letting. A sudden shock to the sympathetic system of nerves will do this, by allowing the muscular coat of all the blood-vessels to dilate.

The blood-pressure in the arteries is expended in causing the blood to flow through the capillaries, so that there is only a very small pressure in the veins. During the dilatation of the chest in the act of inspiration, the blood is sucked towards the chest from the great veins; hence, if one of these is wounded, air may be drawn into the vessel, and so find its way to the heart. Sudden death is the result of this accident, and the blood is found frothed up in the heart.

A very small air-bubble causes death in this way; the accident has occurred in amputating at the shoulder-joint, and special precautions must be taken in this operation to prevent it.

The circulation is chiefly due to the contractions of the ventricles, but the return of the blood by the veins is assisted by the intermittent pressure of the muscles. This squeezes the blood from a segment of the vein, and its return is prevented by the closure of the valves behind, so that muscular pressure always helps the blood on.

Unlike the muscular coat of the blood-vessels, the wall of the heart is composed of a form of striated muscle fibre. This is red in colour, and differs from ordinary voluntary muscle in having no sarcolemma, and in the smallness of its fibres. These consist of oblong muscle-cells united together by a connective substance into fibres, which form a network with each other.

For the general and relative anatomy of the heart, the student must dissect a heart and read its description in some work on anatomy.

The rhythmic pulsations of the heart depend on a set of ganglia in its substance. If you take a piece of muscle from a frog immediately after it is dead, and then pass a current of electricity into it for a very small fraction of a second, the muscle will contract; if you repeat this at intervals of a second, or rather less, the muscle will contract each time; and this is just what the heart will do if you leave it alone.

The nerve-cells in the heart stimulate it regularly, not by a current of electricity, but by some change in the nerves which is not quite understood. Sir James

Paget long ago suggested that the nerve-cells of the ganglia are constantly being charged with some force as the result of their nutrition, and that this force is discharged periodically into the muscle of the heart as soon as it reaches a certain tension; hence the contraction.

If the heart is kept at the right temperature after it is cut out of an animal, it beats as if in the body—that is, its rhythm remains the same. The heart's rate of action is, however, regulated in the body by the pneumogastric and sympathetic nerves.

The former causes the heart to beat more slowly than it otherwise would. When both pneumogastrics are cut, the heart goes on much faster than before; when these nerves are stimulated they pull up the heart, and if the stimulation is sufficient they stop it. The pneumogastric nerves are said to inhibit the heart's action; they act as the reins act on a horse in the hands of a skilful driver.

Certain other fibres which go to the heart accelerate its action; these are called the Accelerator Fibres. They run through the sympathetic, but are connected with the medulla oblongata. As the phenomena are very complex, the student who wishes to understand them must consult a larger work.

The nerves of inhibition and acceleration regulate the action of the heart, so that it sends exactly the right quantity of blood into the aorta, in health, to maintain the normal blood-pressure.

IV.—The Respiration.

Air is drawn into and expelled from the lungs about fifteen or sixteen times in a minute in the adult. This is effected by the movements of the wall of the chest, and the diaphragm. In children the respiration is quicker. One respiration corresponds to from four to five pulsations of the heart in health. When the heart-action is accelerated, the respiratory movements are also accelerated. Any deviation from this is abnormal.

Inspiration is the act of drawing air into the chest.

An ordinary inspiration is such a one as we make unconsciously in ordinary breathing; an extraordinary inspiration is such a one as we make when we take a deep breath. The ordinary muscles of inspiration are those used in the ordinary act; the extraordinary muscles are those which are called into play to take a deep breath. All the muscles which are able to raise the ribs help to expand the cavity of the chest. The ordinary muscles of inspiration are the diaphragm, the external intercostals, and the levatores costarum. The chief extraordinary muscles of inspiration are the pectorals and serratus magnus.

The diaphragm descends in inspiration, but always remains convex towards the chest; the central tendon does not move, as the pericardium is firmly attached to it. The descent of the diaphragm causes the abdominal wall to bulge. The diaphragm is forced back in expiration by the elasticity of the abdominal muscles; the ribs descend by the elasticity of the costal cartilages.

Expiration, or the expulsion of air from the chest, in the ordinary act of respiration, is the result of elasticity.

There are probably no ordinary muscles of expiration. When we expel more air from the chest than we are in the habit of doing in the ordinary act of respiration, we bring into play all those muscles which press on the cavity of the abdomen, and so force up the diaphragm, as well as all those which draw the ribs down. These are called extraordinary muscles of expiration.

The internal intercostals and the triangularis sterni are the first that act, and these are sometimes called ordinary muscles of expiration.

In children the act of respiration is chiefly performed by the diaphragm. This is often called abdominal respiration, as the wall of the abdomen rises and falls with the movement of the diaphragm. In men the movement is more in the lower ribs, inferior costal, and in women in the upper ribs, pectoral respiration. These are spoken of as the three types of respiration.

The lungs occupy the greater part of the cavity of the chest.

Each lung is inclosed in a serous sac, the pleura. The root of the lung consists of the bronchus, the pulmonary and bronchial arteries and veins.

The bronchus, when it enters the lung, divides into branches, like a tree; these branches become smaller and smaller, until they reach a diameter of $\frac{1}{40}$ of an inch; each then divides several times, but the branches become no smaller.

The extremities of the smallest bronchi terminate in the air-sacs; a small group of air-sacs bound together by fine elastic tissue forms a lobule of the lung. The air-sacs are of the same diameter as the bronchus, from which they arise, at the extremity next the bronchus, but they enlarge towards their other extremity; hence they are called Infundibula.

The wall of an infundibulum is a very delicate membrane, which is sacculated over its whole surface. The sacculi are called Air-Cells; these air-cells are about $\frac{1}{50}$ of an inch in diameter.

The outside of the air-sacs is covered by a very close network of small capillaries, uniting the pulmonary artery and vein; a single layer only exists between each pair of adjacent air-cavities, so that the blood has air on both sides of it. The air-sacs are lined by a delicate pavement epithelium, and are bound together by a very fine net-work of elastic fibres. The smallest bronchi consist of a membrane like that forming the infundibula, and they are lined with the same kind of epithelium ; but they have, in addition, on the outside of the membranous coat, a layer of non-striated muscle fibres, chiefly arranged as circular fibres, running round the bronchus : it is the spasmodic contraction of these fibres which produces spasmodic asthma. These are again surrounded by elastic connective-tissue, the external coat of the bronchus.

The larger bronchi have circular cartilaginous rings in the external coat, and they are lined with ciliated columnar epithelium, resting on several layers of spheroidal cells. It is usual to speak of this arrangement as Stratified Ciliated Epithelium.

The bronchi between the smallest and the largest present transitional characters : the cartilaginous rings become irregular in shape, and are found at last only at the angles of bifurcation as small triangular plates.

The whole tissue of the lung is very elastic, so that, as soon as air is admitted to the cavity of the pleura, the lung collapses. The use of this elastic tissue is to cause the whole of the air-cells to enlarge and contract with the enlargement and contraction of the cavity of the thorax. If the lungs were not elastic, the air-cells would be diminished in volume on the surface of the lung only, when the chest is diminished in capacity in expiration. The elasticity of the lung may be said to assist in the expiratory act.

The exchanges between the blood and the air take place by the passage of gases and water through the walls of the lung-cells and capillary vessels.

The lung is nourished by the bronchial arteries, branches of the thoracic aorta, and their blood is returned *partly by the* bronchial veins into the superior intercostal and azygos veins, and partly by the pulmonary veins to the left side of the heart.

The average amount of air changed with each ordinary respiration, in a healthy adult male, is thirty to forty cubic inches, and about five or ten cubic inches less is the average in women. This air is called Tidal Air.

The whole quantity of air that can be changed at a respiration, when the inspiration and the expiration are as great as possible, is called the Vital Capacity. In a healthy man of five feet six inches, this is 217 cubic inches. You must add or substract eight cubic inches for each inch of stature, more or less than this.

Besides this, there is more than 100 cubic inches of air in the chest which cannot be expelled. This is called Residual Air. The air which is capable of being expelled after an ordinary expiration is called Reserve Air; that which is able to be taken in after an ordinary inspiration, Complemental Air.

V.—CHANGES IN THE AIR AND BLOOD IN THE LUNGS.

Ordinary pure air contains 21 per cent. of oxygen. There is only 16 per cent. of oxygen in the expired air; the quantity of oxygen absorbed by the blood is equal, therefore, to 5 per cent. of the whole volume of the air.

The place of this oxygen is taken by an equal volume of carbonic anhydride. This of course contains a volume of oxygen equal to that absorbed.

The air is warmed in the lungs, and is expired at the temperature of the body, or very nearly at the temperature of the body, about 37° Centigrade; it is also saturated with moisture.

The changes in the blood, in the lungs, are as follows: it absorbs oxygen, which combines with the substance of the red corpuscles; it gives up carbonic acid, which is dissolved in the liquor sanguinis; it loses water, and is probably cooled about one-third of a degree Centigrade.

The average weight of blood which passes through the lungs, in an adult, in a minute, is between 12 and 24 pounds; the average amount of air is 120 to 150 cubic inches, weighing about 50 grains.

The cooling of the blood, to heat this quantity of air, would be less than could be measured; the amount of heat given up by the blood in the lungs, small as it is, must depend almost entirely on the formation of watery vapour, which requires a large quantity of heat to form it.

The quantity of oxygen absorbed in twenty-four hours, averages in a healthy adult about 10,000 grains; this measures 18 cubic feet. As only 5 per cent. of the air is removed, this shows that 360 cubic feet of air pass through the lungs in twenty-four hours.

As the changes between the blood and the air depend on the difference in the quantity of carbonic acid and oxygen in the air taken in, and in that in the lungs, it is obvious that suffocation would result from breathing the same air over again, just as rapidly as if no air were taken in.

For health an adult requires at least 800 cubic feet of well-ventilated space, and this is allowed in gaols; in hospitals from 4000 to 8000 feet should be allowed. A very small diminution of the normal amount of oxygen is very deleterious to health.

The movements of respiration are reflex. The pneumogastric nerve supplies the tissue of the lung, and any increase of the quantity of carbonic acid in the blood, or in the lungs, acts as a stimulus to the respiratory act. The motor nerves are the branches of the cervical and brachial plexus and the dorsal intercostals.

Injury to the spinal cord, above the origin of the phrenic nerves, cuts off all the respiratory nerves between the medulla, where the centre of the respiratory act is situated, and the muscles; hence death occurs at once by the arrest of the respiratory act.

The sounds of speech are produced by the air, which is sent from the lungs with varying degrees of force, setting the vocal cords into vibration.

The quality of the sounds, in speaking and singing, is produced by the varied tension of the vocal cords, the size of the opening in the glottis, the size and shape of the mouth, and the position of the tongue and soft palate, as well as by the force and quantity of the air set in motion by the respiratory muscles.

Coughing is a sudden expulsion of air. This is effected by first approximating the vocal cords, and so closing the rima glottidis, and compressing the air in the lungs. Then the vocal cords are separated, and the air rushes out suddenly.

Sighing is a long deep inspiration, sneezing a sudden expiration through the nares. Laughing is an interrupted expiration caused by vibratory opening and closing of the vocal cords.

VI.—Animal Heat.

Man and the so-called warm-blooded animals keep the temperature of the body at a constant standard.

In man the normal temperature in health is between 37° and 38° Cent.—98·6 to 100° Fahr. The former is the normal temperature in the axilla; perhaps the latter is a little exceeded by the blood in the right side of the heart, which is the hottest in the body.

Whatever the temperature of the air, this temperature is maintained.

The source of heat is the combination of the material

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of the body with oxygen. The temperature is regulated by the evaporation of water from the surface and in the lungs; when the temperature rises above the normal standard, more blood is sent to the skin, sweat is formed on the surface, and the evaporation of this cools the body.

The amount of heat formed in the body is also variable, and depends on the nourishment of the body, the amount of exercise taken, and probably on the condition of the nervous system. The question is, however, very complex, and cannot be entered on more fully here.

The use of fur in animals, and of clothing in man, is to protect the body from too great a loss of heat.

Air is a bad conductor of heat, but it takes heat away from the body by convection; the clothes and fur keep the air from moving over the surface of the body, so that the heat cannot escape. Light woollen textures are warmer than more closely woven stuffs, as the latter conduct heat to their surface, and so lose it by parting with it to the air.

VII.—Food.

1. *Inorganic Food:* Water and Table Salt, Na. Cl.

Oxygen is considered by some as a form of food, but as the respiration is distinct from the nutrient functions, it is better not to consider oxygen as a food at all, but as the supporter of the combustive processes of life.

2. *Organic Foods:* Divided into nitrogenous and non-nitrogenous.
   - (*a*) *Nitrogenous* foods are the various forms of albumens, called Proteids, because they all yield a chemical body, called *Protein.*

Albuminous or proteid compounds are found in both animal and vegetable food; from the former we have albumen, from blood, and from the eggs of birds; syntonin and fibrin, from muscular tissue (lean meat); and casein from milk. From the latter, gluten from wheat-flour, and legumin from the seeds of the leguminosæ. All vegetable food contains a percentage of some form or other of albumen.

Gelatin is a nitrogenous animal principle, but its value as food is not great; some consider that it is absolutely innutritious. It is not a protein-yielding body.

(*b*) *Non-nitrogenous* foods.

There are two classes of non-nitrogenous foods:

(1) Starches and sugars, which have their oxygen and hydrogen in the proportions to form water, and of which the carbon only is available for the production of heat and motion.

(2) Oils and fats: compounds of fatty acids with glycerine, in which there is an excess of hydrogen over the quantity which would form water with the oxygen of the compound. In these both carbon and hydrogen are available for oxidisation and the production of heat and movement.

A strong man who works hard requires about ten unces of carbon, and about three hundred grains of nitrogen in his food during twenty-four hours, in such a form as can be incorporated with the blood.

Bread contains thirty per cent. of carbon and one per cent. of nitrogen, and lean meat has ten per cent. of carbon and three per cent. of nitrogen; a mixture of the two is therefore a proper and economic form of diet.

If man feeds on bread only, he has to eat at least four pounds to get the necessary amount of nitrogen, and he takes twice as much carbon as he wants. If he feeds on meat only, he must eat about six pounds to get the requisite amount of carbon, and he takes six times the quantity of nitrogen he requires.

In either case he taxes the excretory organs to get rid of the unnecessary portion of his food.

In cold climates more, and in hot climates less, carbon is necessary. A portion of fat is also necessary, apparently because it aids some part of the digestive process. Vegetable foods, especially green vegetables, are necessary, owing to the potash salts they contain; their absence gives rise to scurvy.

VIII.—The Alimentary Canal.

The alimentary canal consists of the mouth, the pharynx, the œsophagus, the stomach, and the intestines.

The teeth are permanent and temporary. The temporary set are called Milk-Teeth; they are twenty in number: four incisors, two canines, and four milk-molars in each jaw.

The central incisors are cut first, those of the lower jaw appearing above the gum before those of the upper are erupted; they are cut about seven months after birth; the lateral incisors are cut about the ninth *month,* the first molars at the end of the first year, the canines at the eighteenth month, and the second molars at the end of the second year.

The first permanent teeth appear behind the posterior milk-molars; they are the first permanent molars. They are erupted before any of the milk-teeth are shed, at six years of age.

A child of six has therefore twenty-four teeth; twenty temporary and four permanent teeth. Beware of mistaking the first permanent molars for milk-teeth, or you will get into trouble.

The milk-teeth are then shed, and replaced by permanent teeth in the following order: the central incisors in the seventh year, the lateral incisors in the eighth year; the first milk-molars are replaced by the anterior bicuspids in the ninth, and the posterior milk-molars by the posterior bicuspids in the tenth years; the canines are replaced by permanent teeth about the twelfth or thirteenth year. The second permanent molars appear at twelve, and the third permanent molars, or wisdom-teeth, are seldom erupted before the eighteenth year, and often do not make their appearance till ten years later; they are also frequently never developed. The full complement of teeth in the adult is therefore thirty-two.

The milk teeth are developed from papillæ, which appear in a groove—the Dental Groove—on the alveolar edges of the jaws. The papillæ afterwards become inclosed in capsules formed from the primitive dental groove. They are developed in these capsules, and are erupted by the simultaneous growth of the teeth and the ossification of the alveoli.

The twenty anterior permanent teeth succeed the milk-teeth, and are developed from a portion of the corresponding papilla, which becomes separated from the rest before the formation of the milk-tooth, and inclosed in a cavity in the jaw—the Cavity of Reserve.

The posterior permanent teeth are developed from papillæ derived from the papilla of the tooth immediately in front of them.

A tooth consists of a crown, and a root or fang; between the two is the neck of the tooth. The tooth consists of a substance called Dentine, or ivory. In the centre of the dentine is the Pulp Cavity, which contains a plexus of vessels, a nerve, and a number of cells—pulp. The dentine of the crown is covered by Enamel, that of the root by Crusta Petrosa. At the neck of the tooth both the enamel and the crusta petrosa become very thin, and their edges meet.

Dentine consists of a hard matrix, permeated from within outwards by minute dichotomously branching dentine tubules. The average diameter of the dentine tubules is $\frac{1}{4500}$ of an inch. They contain processes of the cells lining the pulp cavity; these cells have the same relation to the dentine that the bone corpuscles have to bone.

Enamel is the hardest substance in the body; in the fully-developed tooth it has only 2 per cent. of animal matter in it. It consists of hexagonal prisms, placed perpendicularly to the surface of the dentine; these run through the whole thickness of the enamel, but are not more than $\frac{1}{5000}$ of an inch in diameter.

Crusta petrosa has the same structure as bone, but there are no Haversian canals, and the lacunæ are larger and less regular in their distribution; they are also fewer in number.

The tongue consists of muscular tissue of the striated kind, arranged in bundles called Linguales, and of larger muscles, which unite it to the jaw, the hyoid bone, and the styloid process of the temporal bone. The muscles have glandular tissue and fat between them, and are inclosed in the mucous membrane of the *tongue.*

The linguales alter the form of the tongue, and are therefore called Intrinsic Muscles ; the other muscles move the tongue as a whole, and are called Extrinsic Muscles.

The tongue is divided into two halves by a fibrous septum running vertically from the tip to the base.

There are two sets of longitudinal linguales: an upper set, which run from the tip to the base of the tongue, immediately under the mucous membrane of its dorsum ; another set are situated near the inferior part of the organ. These sets are separated from each other by transverse linguales, which arise in the septum and extend to the edges of the tongue. A fourth set run vertically from the mucous membrane of the dorsum to the under surface of the tongue.

The mucous membrane has simple papillæ all over it, and three kinds of compound papillæ on the dorsum. These are Filiform, Fungiform, and Circumvallate.

The filiform papillæ are organs of touch, and end in numerous filiform prolongations composed of epithelial cells. The fungiform papillæ are chiefly situated at the tip and edges of the tongue. The circumvallate papillæ are very large fungiform papillæ.

There are about seven circumvallate papillæ, forming a V-shaped line at the back of the tongue; each is surrounded by a groove. The fungiform and circumvallate papillæ are organs of taste.

The articulation of many sounds is connected with the shape and position of the tongue. It is an organ of taste and of deglutition.

The pharynx is a muscular sac suspended from the base of the skull. It consists of the three constrictor muscles, which are red and striated; it is lined by mucous membrane continuous with that of the mouth and nares on the one hand, and with that of the larynx *and œsophagus* on the other.

Between the muscles and the mucous membrane there is a layer of fibrous connective tissue. This is thick and dense above, but gradually thins away below; it is called the pharyngeal aponeurosis.

The œsophagus has three coats: an external connective tissue coat; a middle muscular coat, consisting of pale non-striated muscle, arranged in two layers—an external longitudinal and an internal circular layer.

This disposition of the muscle fibres is the same throughout the rest of the alimentary canal.

The upper part of the muscular coat of the œsophagus contains a number of striated muscle fibres continuous with the inferior constrictor muscle of the pharynx.

The third, or mucous coat is arranged in longitudinal folds: it has numerous racemose mucous glands studded over it, and the œsophagus is lined with stratified pavement epithelium, like that of the mouth.

The stomach is a dilatation of the alimentary canal. Its wall is composed of three coats, like the œsophagus. The external connective coat is, however, very thin, and the whole organ is covered by the visceral layer of the peritoneum, which may be said to take the place of the connective coat of the œsophagus.

It is usual to speak of the external coat of the stomach as peritoneal, and to regard the connective tissue as a portion of the peritoneal coat—subperitoneal. The muscular coat consists of an external longitudinal, a middle circular, and an internal oblique layer.

The oblique layer is most developed at the cardiac, or œsophageal end of the stomach; the circular is most developed at the pyloric, or duodenal end of the organ. This latter forms the sphincter of the pylorus, and regulates the passage of the food from the stomach to the intestine

The mucous membrane of the stomach is corrugated *both longitudinally* and circularly, except when the organ is very much distended; it is also honeycombed all over its surface with minute pits, which can be easily seen with a pocket lens. These are not obliterated by over-distension of the stomach. It is covered by a single layer of columnar epithelium, except for a short distance from the opening of the œsophagus, where the epithelium is like that of the gullet.

The mucous membrane consists of closely-packed tubular glands or follicles, several of which open into each honeycomb-like depression on the surface; these are the gastric glands.

The intestine has the same coats as the stomach, except that the muscular coat has only two layers, as in the œsophagus. The mucous membrane has special characters in different parts of the intestine. The second and third parts of the duodenum, the cœcum, the ascending and descending colon, and a great part of the rectum, are not surrounded by peritoneum.

IX.—Changes of the Food in the Mouth.

The food in the mouth is subjected to the action of the teeth and the saliva—Mastication and Insalivation.

Mastication is effected by the action of the flat crowned molars and premolars. A lateral and backward and forward motion is given to the inferior maxillary bone by the pterygoid muscles, and the food is kept between the teeth by the action of the tongue and the buccinator muscles. A troublesome symptom in facial paralysis is that the food slips down between the cheek and the lower jaw, so that it cannot be properly masticated.

At the same time that the food is triturated between the molar teeth, it is mixed with the saliva from four principal pairs of salivary glands—the parotids, the submaxillary, the sub-lingual, and the intra-lingual glands. Beside these, there are smaller glands studded over the mucous membrane of the mouth.

The salivary glands are of the type of gland called Racemose. They consist, like the pancreas, Brunner's glands in the duodenum, and the mammary gland, of a branching duct, the terminations of which are membranous sacs called Acini. The duct consists of three coats, an epithelial lining, a middle muscular coat, and an external connective tissue coat.

The acini are formed of thin structureless membrane. They are lined with glandular spheroidal epithelium, and are covered on their outside by a close plexus of capillaries. Several acini are bound together to form a lobule of the gland.

Under ordinary circumstances, glands are pale, but when they are actively secreting, they become red, by reason of the much larger quantity of blood which passes into them. This change is due to the dilatation of the arteries which supply them. In the case of the salivary glands, this results from the stimulation of the sensory nerves of the mouth and tongue.

This stimulation is transmitted by the sensory nerves to the medulla, and is reflected by the facial and its branches, the greater and lesser petrosal and chorda tympani nerves, through the otic and submaxillary ganglia.

The arteries of the gland are normally kept in a state of contraction by the sympathetic nerves which supply them. The action of the ganglia appears to be to neutralise, or inhibit, the action of the sympathetic, so that the arteries dilate.

The thought of, or smell of, food acts similarly through the medulla on these glands; the movements of the mouth, in speech and mastication, also stimulate the salivary glands to increased action. Certain poisons in the blood, as iodides and mercury, give rise to profuse salivary secretion—salivation—probably by direct stimulation of the gland.

The parotid saliva is the most copious and the most watery. It is poured into the mouth by Stenson's duct, which opens in the cheek on a level with and just outside the first molar tooth in the upper jaw. The saliva from the other glands is more viscid and less abundant than that of the parotids.

Parotid saliva has only about six parts of solid matter in 1000 parts. The saliva from all the glands is alkaline, and its solid matter consists of salts, mucus, ptyalin, and sulphocyanide of potassium—the latter substance in very minute quantities.

The active principle of the saliva is ptyalin. It acts on the starch of the food, and converts it into grape sugar.

The other uses of the saliva are the solution of the sapid particles of the food, thus enabling us to taste, and the mechanical softening of the food, enabling it to be swallowed. It also keeps the mouth moist in speaking. The sulphocyanide is supposed by some to prevent the growth of fungi in the interior of the mouth.

The quantity of saliva secreted in the day is about 3 pounds.

X.—Deglutition.

The act of Deglutition, or swallowing, is divided into three stages. The first is the passage of the food through the mouth as far as the anterior pillars of the fauces; this is voluntary. The food is pressed backwards between the tongue and the hard palate, by placing the tip of the tongue against the upper and back part of the front incisors of the upper jaw, closing the mouth to fix the hyoid bone, and forcing the tongue from before backwards against the hard palate.

The second part of the act is almost entirely reflex, and when once fairly commenced is entirely beyond the control of the will.

The food, passing the anterior pillars of the fauces, sets up a complex series of reflex acts. The larynx is raised and pulled forwards, so that the epiglottis is pressed against the back of the root of the tongue and is so closed, the tongue overhanging the glottis for the more secure protection of the air-passage. The epiglottis is held down by its depressor muscles, and the rima glottidis is closed by the approximation of the vocal cords.

That the root of the tongue is sufficient to prevent the passage of food into the larynx is shown by the act of swallowing being safely performed by persons who have lost the whole of the epiglottis by ulceration.

At the same time the posterior nares are cut off from the pharynx by the raising of the soft palate, the approximation of the posterior pillars of the fauces to each other, and the drawing forward of the posterior wall of the pharynx by the contraction of the palato-pharyngeal muscles, which lie in the posterior pillars of the fauces.

The way being thus prepared, the food passes down the back of the tongue, being lubricated in its passage past the tonsils by their viscid mucous secretion, and is seized, and contracted upon, successively, by the constrictors of the pharynx.

The third stage is the passage of the food through the œsophagus. This is effected by a peristaltic contraction of the œsophagus, commencing above; the food, which forms a bolus, is successively grasped by the circular fibres from above downwards, whilst the œsophagus is drawn upwards by the contraction of its longitudinal fibres.

Fluids are swallowed in the same manner as solids;

but it is more difficult to swallow them if the mechanism of deglutition is disturbed in any way, as the contractions of the muscular tissue of the pharynx and œsophagus must be exactly performed, or they escape into the mouth and nares.

XI.—DIGESTION IN THE STOMACH.

After the food enters the stomach it is acted upon by the gastric juice, and is kept in continual movement by the action of the muscular coat of the stomach. The whole contents of the stomach are churned with a rotatory movement towards the pylorus along the greater curvature, and back along the lesser curvature of the organ. This continues as long as any food remains in the stomach.

The changes which the food undergoes are partly of a mechanical nature, and partly chemical. An ordinary meal requires from three to five hours for complete digestion in the stomach.

The tubular glands of the stomach are of two kinds: Peptic Glands, which occupy the whole surface of the mucous membrane, except about one-fifth near the pylorus, and Mucous Glands, which occupy this fifth.

The peptic glands consist of a short tubular duct, at the bottom of which there are several follicles containing large cells (Peptic Cells); these secrete the gastric juice. The mucous glands have a long duct, and rudimentary follicles without any peptic cells; they probably secrete mucus only.

The gastric juice consists of water, small quantities of salts from the blood, an active ferment-like body called Pepsin, and hydrochloric acid. Pepsin is a powerful solvent of albuminous tissue, in the presence of hydrochloric acid, but is inert in neutral or alkaline solutions.

After death the gastric juice rapidly dissolves the coats of the stomach. It is supposed that the reason why the gastric juice does not dissolve the stomach during life, is that the mucous membrane is kept alkaline by the circulation of the alkaline blood.

There is pepsin in the secretion of the gastric glands, in the glands themselves; but the gastric juice only becomes acid at the orifices of the glands. The origin of the acid is at present unknown; it appears to be formed on the surface of the mucous membrane.

Gastric juice is secreted in large quantities during stomachic digestion. About twenty to thirty pounds are formed during the day, so that a large meal probably requires about fifteen pounds of gastric juice for its digestion.

As the stomach only contains a pint or two of this fluid at most at a time, it is being constantly absorbed by the veins of the stomach as it is secreted. In this way, whatever is dissolved in the gastric juice is rapidly absorbed, and finds its way at once into the blood. All the soluble substances in the food are so absorbed.

The albumen of the food is first coagulated by the formation of lactic acid, at the expense of the sugar and starch, unless it has been first solidified by cooking. It is then dissolved by the pepsin and converted into a substance called Albuminose, or Peptone; in this form it is absorbed by the capillaries and veins of the stomach with the gastric juice.

Peptone differs from albumen in not being solidified in the presence of an acid; it is not coagulated by heat, but the most important physiological difference is that it is capable of passing through an animal membrane, which albumen is incapable of doing, except to a very limited extent—that is, it is dialysable; the peptone is reconverted into albumen in the blood, and is so retained in the circulation.

The conversion of starch into grape-sugar, begun in the mouth under the influence of the saliva, continues slowly in the stomach. About one-third of the albumen of the food is dissolved, converted into peptone, and absorbed. The connective tissue of muscle is dissolved, the fat is set free from its connective and albuminous envelopes, and the whole of the digestible food which is not absorbed is converted into a grey creamy fluid called *Chyme*. This is passed little by little through the pylorus into the duodenum.

Solid indigestible masses of food are passed into the duodenum only after many hours, and are frequently vomited up rather than passed. Much dyspepsia has its origin in the want of proper mastication. Children and old people are especially apt to bolt their food; hence it should always be properly reduced to a mince before they are allowed to eat it. This is especially important with young children.

The presence of food in the mouth or stomach excites the secretion of the gastric juice; the wall of the stomach becomes redder, from the larger quantity of blood sent to it as the result of inhibition of the action of the vasomotor branches of the sympathetic. This is a reflex act, similar to that which has been described in the case of the secretion of saliva.

XII.—Structure of the Small Intestine.

The small intestine is divided into three parts. The first, the Duodenum, is about eight inches in length; the second, the Jejunum, is eight feet; and the third, the Ileum, is twelve feet in length.

Except the duodenum in the second and third parts of its course, the whole is inclosed in peritoneum, and the jejunum and ileum are attached to the spine by a fold of *peritoneum* called the mesentery.

The muscular coat has the same characters throughout the small intestine, and consists of an external longitudinal and an internal circular layer of non-striated muscle fibre.

The mucous coat differs in different portions of the tube. It is thickest in the duodenum and jejunum, and thinnest in the ileum. It is covered thickly with villi throughout, and it is also thickly set with tubular glands, called Lieberkuhn's follicles: the duodenum has also numerous racemose glands called Brunner's; these are not found in the jejunum or ileum. Lastly, the glands of Peyer are only found in the lower part of the ileum.

The mucous membrane in the lower three-fifths of the duodenum, throughout the jejunum and in the upper half of the ileum, is thrown into transverse folds, which cannot be obliterated by stretching the intestine —Valvulæ Conniventes. They are largest in the lower part of the duodenum, and gradually diminish in size and number in the jejunum and ileum.

The valvulæ conniventes do not any of them entirely encircle the bowel; they are crescentic folds, but they overlap each other, so that the interior of the bowel is everywhere covered by them. The largest project half an inch into the tube; their purpose is to increase the surface for the absorption of the digested food, and to delay its passage through the small intestine.

The villi look to the naked eye like the pile of velvet; they are largest where the valvulæ conniventes are largest, and are smallest where these are absent or least developed. They are flattened papillæ, and each contains a capillary plexus and a small lacteal.

The whole mucous membrane is covered by a single layer of columnar epithelium.

Between the mucous membrane and the muscular coat there is a layer of loose connective tissue—the

Submucous Tissue. This contains a plexus of blood-vessels, and a plexus of varicose lacteals connected, on the one hand, with the lacteals of the villi, and on the other, with those of the mesentery.

The mesenteric lacteals converge, and, after passing through the mesenteric glands, empty themselves into the Receptaculum Chyli, the commencement of the thoracic duct, at the root of the mesentery.

Peyer's patches consist of minute vesicles arranged in oblong patches. They are situated on that portion of the intestine which is furthest from the mesentery, have their long axis in the direction of the length of the bowel, and measure from half an inch to three inches in length, and from a quarter of an inch to three quarters of an inch in width; they become ulcerated in typhoid fever.

The vesicles of which these patches are formed contain a large number of cells, like white blood-cells; they are ductless glands, and probably have some relation to the lymphatic system, as they are closely surrounded by the lacteal plexus.

The submucous tissue also contains a plexus of sympathetic fibres and cells; this is called Meissner's Plexus, after its discoverer: the peristaltic movements of the intestine are perhaps due to the action of this system of nerves and nerve-cells; it is to be regarded as the intrinsic nervous system of the intestine.

The duct of the pancreas, and the common bile duct, open together into the duodenum in the second part of its course.

XIII.—Digestion in the Small Intestine.

After the chyme passes into the duodenum it is mixed with the bile and the secretion of the pancreas.

Bile is the secretion of the liver. In man it is of a bright orange colour when pure, but becomes green by oxidisation. It is neutral in reaction, and contains from ten to twelve per cent. of solids. The following is the composition of the bile :

Bilin : seven parts.
Cholesterin : one to three parts.
Mucus and colouring matter : two to three parts.
Salts : about half a part, and water to make up 100 parts.

Bilin consists of glyco- and taurocholate of soda. It forms soaps with free fatty acids. It is estimated that 56 ounces of bile are secreted in twenty-four hours.

The secretion of the pancreas is strongly alkaline, and contains three active principles. These used to be called pancreatin. One of these substances acts on starch and converts it into grape-sugar.

A large quantity of the starch of the food is unchanged by the saliva ; this passes into the intestine, and is dissolved by the pancreatic secretion.

The second active principle acts on albumen, and digests the residue left undigested in the stomach ; the third splits up the fats of the food into fatty acids and glycerine.

The fatty acids form soaps with the bilin and the free alkali of the pancreatic secretion ; this is the cause of the emulsification of the chyme, which becomes white and opaque, and is then called chyle.

The secretion of the glands of the mucous membrane of the small intestine is of a yellow colour ; it is strongly alkaline, and probably assists the secretion of the pancreas in the solution of the albumens of the food. It is called Succus Entericus.

The changes which take place in the albumens under the influence of this secretion and that of the pancreas are very complex. A substance allied to casein, the albumen of milk, is formed, together with a number of waste products.

The reader is referred to Dr. Foster's work on physiology for full information on this subject, and to Cook's Tablets for a very good *resumé.* A knowledge of the chemistry of the process is only required in the higher examinations.

Absorption in the intestine is partly effected by the capillaries of the villi, and partly by the lacteals.

The emulsified fats are not dissolved, but are held in suspension by the fluid of the chyle. They form what is called the molecular basis of the chyle, and are absorbed by the epithelium of the villi, from which the particles pass into the lacteals, together with the albuminous fluid in which they are suspended.

The villi are surrounded by a layer of non-striated muscle fibre immediately beneath the epithelium. They consist of spongy tissue called Adenoid Tissue,* and become turgid with the absorbed chyle. The muscular fibres then contract and force the chyle into the submucous lacteals, from which it passes into the mesenteric lacteals, and after traversing the mesenteric glands, into the receptaculum chyli. It then passes through the thoracic duct, and so into the venous system.

The thoracic duct opens into the junction of the left jugular and subclavian veins.

The changes which the chyle undergoes in its passage from the villi of the intestines to the veins are as follows: Before entering the mesenteric glands, it is an albuminous fluid, with an abundance of molecular fat and very few cells, like white blood-cells, derived from the tissue of the villi; it coagulates by heat, but does not coagulate spontaneously. After passing through the mesenteric glands it coagulates spontaneously, and far more rapidly than blood; this is due to the formation of fibrin-yielding materials. The number of white cells is also greatly increased.

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* See structure of lymphatic glands.

In the thoracic duct the chyle becomes diluted by the admixture of the lymph: it is believed that the white cells of the chyle become converted into red blood corpuscles, and the chyle in the upper part of the thoracic duct is of a faint rose colour from the coloration of the cells it contains.

The mixed lymph and chyle move through the thoracic duct, during active digestion, at the rate of about twelve inches a minute. The chief cause of this movement is the absorption of fresh chyle by the smallest lacteals, and of fresh lymph by the lymphatics of the tissues.

The flow of chyle and lymph through the thoracic duct is aided by the existence of valves like those of the veins. The flow is also aided by the peristaltic contraction of the muscular coat of the lacteals and thoracic duct. The whole structure of the tubes is the same as that of the veins.

It is also thought that the flow of blood through the subclavian vein exerts a suction on the contents of the thoracic duct, and so aids its movement.

It is estimated that about thirty pounds of mingled lymph and chyle passes through the thoracic duct into the blood in the twenty-four hours. Of course the greater part of this is lymph.

The only difference between the lymphatics and the lacteals is that the latter contain an opaque fatty fluid, derived from the cavity of the intestine, and the former contain a clear fluid derived from the tissues.

The origin of the lymph is from the blood. The fluid portion of the blood exudes through the walls of capillaries, and so bathes all the tissues. These remove a great part of the dissolved solids for their own nutrition; and the water, with the remains of the dissolved solids, passes back to the blood through the lymphatics as lymph.

The passage of the food through the small intestine occupies on an average about twelve hours, and during this passage the greater part of the nutrient material is absorbed; the waste residue passes through the ileo-cæcal valve into the cæcum, where it remains some time and undergoes chemical changes. It is here that it first acquires the character of fæces.

During the passage of the fæces through the large intestine, water and soluble materials are absorbed, and the peculiar secretion from the tubular glands of the large intestine is added to them. More water is absorbed from them than is added to them, so that they become solid.

The digestive and absorbent power of the large intestine is very small, but the partial absorption of nutrient enemata proves the existence of this function.

The fæces consist of the undigested residue of the food, the residue of the bile, and the secretion of the tubular glands of the large intestine. The average weight of the fæces in man is five ounces in the twenty-four hours; but the quantity is subject to very great variations.

XIV.—The Liver.

The liver is the largest gland in the body; in an adult man it weighs from three to four pounds.

It differs from other glands in its chief supply of blood being venous. The vena porta is formed by the junction of the splenic and superior mesenteric veins, and as the splenic vein receives the inferior mesenteric vein, all the blood from the spleen, the stomach, and intestine passes through the liver before it reaches the general circulation.

After passing through a special set of capillaries in the liver, the blood of the portal vein reaches the branches of the hepatic veins, by which it is conveyed into the hepatic veins and inferior cava.

The easiest method of describing the structure of the liver is to begin with the hepatic veins. These divide and subdivide, until they form the sub-lobular veins.

The branches of the sub-lobular veins are intra-lobular veins; each is surrounded by a lobule of the liver. These lobules are surrounded by a net-work of fine veins, the ultimate branches of the portal veins; these are called inter-lobular, because they are between the lobules.

The portal vein enters the transverse fissure of the liver with the hepatic artery and duct, and these three structures are surrounded by a connective tissue sheath called the Capsule of Glisson.

The hepatic artery supplies this sheath with blood, as well as the connective tissue and capsule of the liver; it empties its blood partly into the portal, and partly into the hepatic veins.

The hepatic duct has the same course as the portal vein, and terminates in a plexus of minute vessels, which surround, but do not enter, the lobules.

The capillaries of the liver form a radiating plexus in each lobule, uniting the inter- and intra-lobular veins.

The lobules of the liver consist of cells $\frac{1}{1000}$ of an inch in diameter. Each cell has one or more nuclei, and contains oil globules and granules of brown pigment; they are arranged in a radiating manner, between the capillaries of the lobule, around the intra-lobular vein.

When a portion of the liver is cut across, the portal veins, being loose in Glisson's capsule, empty themselves and collapse. The hepatic veins are adherent to the *liver tissue,* and therefore remain open.

The functions of the liver are the conversion of certain constituents of the food into a combustible material called Glycogen, and the excretion of bile.

The first is called the glycogenic function of the liver. Glycogen is a substance allied to starch, and readily convertible by fermentation into grape-sugar and alcohol. It is not, however, converted into grape-sugar in the healthy human body, although it is possible that it is converted into sugar in diabetes. It is probably, normally, either oxidised for the production of heat and work, or converted into fat.

Glycogen is derived from the grape-sugar formed in the digestive process and absorbed by the vessels of the stomach and intestine; and it is also derived, though in less quantity, from the albuminose absorbed by the same vessels, and possibly also from some of the constituents of the blood: the nitrogenous residue of these substances being converted into urea, or uric acid.

The bile must be regarded as a residual product, formed partly in the assimilation of various materials into glycogen, and partly from the waste material of the blood and tissues. It appears probable that the bilin is in part, at least, re-absorbed in the intestine, and re-excreted by the liver. Dr. Brunton thinks that this is shown by the marked diminution of bile for some days after the intestines have been rapidly emptied by a purge.

The quantity of bile, 56 ounces, formed in the twenty-four hours is either over-estimated, or the bilin is in part re-absorbed.

XV.—SECRETION.

Secretion is the process by which the various fluids are separated from the blood, either for use in the organism, or for elimination from the body.

The saliva and the gastric juice are examples of the former class of fluids; these are called secretions in the more restricted sense of the term. The sweat and the urine are examples of the latter; they are called excretions because they are formed to be excreted or eliminated from the body.

Both secretions and excreta* are derived from the blood, and are separated from it by the epithelial cells of glands.

The constituents of the excreta exist in the blood, and are separated from it by the agency of the excreting cells. The constituents of the secretions are formed in the secreting glands.

XVI.—MILK.

Milk is a very complex and typical secretion, formed for the nourishment of the infant.

Milk contains all the constituents of food, in the proper proportion for the nutrition of the infant.

The composition of milk is as follows: A thousand parts of milk contain about 110 parts of solid and the rest consists of water. Rather less than half the solid matter is sugar of milk, and nearly a third is casein, a form of albumen in combination with soda; hence casein is usually called alkali albuminate by chemists. About a quarter of the solid matter consists of butter, a peculiar form of fat; and two parts in a thousand consist of the various salts of the blood.

A portion of the sugar of milk is very easily converted into lactic acid; the milk becomes sour, and as a consequence the albumen solidifies—curdles. The residue is called whey.

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* That part of the fæces which is derived directly from the *food excepted*: this is considered excrementitious.

The milk is normally curdled in the stomach before its casein is converted into peptone by the gastric juice.

The butter exists in the milk in molecular particles, which can be seen with high powers of the microscope. It is this which renders the fluid semi-opaque.

Secretion differs but little from ordinary nutrition. The cells of the gland take certain constituents from the blood, and form the secretion with these. The secretion is then either exuded from the cells, or the cells themselves burst and degenerate, and are succeeded by fresh cells.

The former process appears to be the more usual.

Many of the cells of the mammary gland undergo disintegration during the formation of milk.

XVII.—THE KIDNEYS.

The most typical excretion is the urine. It is formed by the kidneys, which are compound tubular glands.

The kidney weighs about five ounces in the male, and the left kidney is usually a little heavier than the right.

The kidney is covered by a thin fibrous capsule, continuous with the outer coat of the ureter. This capsule sends very delicate fibres into the interior of the organ for the support of the gland tissue; it is, however, easily stripped off by tearing the connections between it and the fibrous network of the interior of the organ. This leaves the surface of the kidney slightly granular.

The organ is seen in section to consist of two parts: a very vascular cortical portion, and a paler, less vascular medullary portion.

The medullary portion consists of from ten to sixteen pyramids, arranged with their apices towards the hilus of the organ, and their bases towards the surface. Observe that the pyramids are entirely separated from each other, and from the surface of the kidney, by cortical substance.

The apices of the pyramids are seen projecting into the calices of the kidney. The calices unite to form the expanded upper end of the ureter, called the pelvis of the kidney.

The pyramids consist of straight dichotomously branching urine tubes. These consist of a fine membrane lined with columnar epithelial cells; they are from $\frac{1}{300}$ to $\frac{1}{500}$ of an inch in diameter.

Except a few nearly straight vessels, which branch like the urine tubes, and a little connective tissue, the urine tubes form the whole substance of the pyramids.

At the bases of the pyramids some of the urine tubes turn back and form loops before they finally leave the pyramids: these are the loop tubules of Henle; they are of smaller diameter than the rest of the urine tubules.

The cortical portion of the kidney also consists in great part of the urine tubules: after these leave the pyramids they become much convoluted, but they do not branch. They terminate in spheroidal capsules about three times the diameter of the tubes; these are the Malpighian Capsules.

The renal artery enters the kidney by the hilus. It breaks up into numerous branches, which pass at once into the cortical substance between the pyramids.

The arteries then branch in the cortical substance somewhat after the fashion of an espalier.* They give off some branches which pass at once into the pyramids, and end in capillaries in the usual way, but the majority remain in the cortical portion of the kidney and end in the Malpighian tufts.

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* A fruit tree, with its branches trained at right angles to *the trunk.*

These are contained in the Malpighian capsules. The artery enters the capsule at the point opposite to that by which the capsule is attached to the urine tube; after entering the capsule, the artery breaks up into several branches. These are rolled together into a ball—the Glomerulus; in the centre of the ball they reunite and form a single vessel, which leaves the capsule close to the artery entering it.

The vessel going to the glomerulus is called the afferent artery, that leaving it is called the efferent artery — some also call it the efferent vein. The efferent vessel then breaks up into a capillary plexus on the nearest urine tubes, and these end in the tributaries of the renal vein.

The Malpighian capsules are really expansions of the urine tubules, which form a double membrane, investing the glomerulus just as the pleura invests the lung.

The whole of the interior of the Malpighian capsule is lined with a layer of very delicate pavement epithelium. The tuft and capsule together are called a Malpighian Body.

The convoluted portion of the urine tubules is lined with spheroidal glandular epithelium. It is scarcely to be distinguished from the columnar variety of epithelium.

The ureter and pelvis of the kidney have an external connective tissue coat, a middle muscular coat of unstriated fibres, and an internal membranous lining continuous with the mucous coat of the bladder, with columnar epithelium on its inner surface.

XVIII.—THE URINE.

The urine is the means by which the nitrogenous waste is eliminated from the system. It consists of water having urea, and traces of bodies allied to urea, uric acid, various salts, and colouring matter, in solution.

Its normal reaction is acid, from an abundance of acid phosphates, but it is sometimes alkaline.

When the alkalinity of the urine is due to a fixed alkali, it is simply the result of a diet consisting of vegetable matter containing a large percentage of potash; if the alkalinity is due to ammonia, it is abnormal, and the result of the decomposition of the urea.

The urine is most acid during fasting; it often becomes neutral during the digestion of a meal.

The water of the urine is excreted by exudation through the walls of the vessels which form the Malpighian tufts. The cause of this transudation is the blood-pressure in the vessels of the tuft; this is maintained by the efferent being smaller than the afferent vessel.

Some of the salts are excreted with this fluid, but the greater part of the solid constituents are eliminated by the cells of the convoluted tubules.

The quantity of water excreted depends on the blood-pressure, and when the sympathetic nerves of the abdomen are divided, the blood pressure is so reduced that no water is excreted. A cold-bath, by increasing the blood-pressure, gives rise to a copious flow of watery urine.

If indigo in a state of fine division is injected into the blood of an animal, it will be excreted as a solid by *the urine; and* if the sympathetic be divided, it will accumulate in the epithelial cells of the convoluted tubules and in the tubules themselves, as no water will be excreted to wash them out.

The quantity of water excreted by the kidneys is subject to great variations, and depends on the quantity of fluid taken; the average is fifty to sixty ounces in the twenty-four hours. More is excreted in the winter than in the summer, as in warm weather more is excreted by the skin and lungs.

The solid matter in the urine varies much at different times in the day.

The urine secreted in the morning, when neither food nor drink has been taken for some hours, has the most definite composition; it is called Urina Sanguinis. That an hour or two after a meal has most solid matter; it is called Urina Cibi. That after a copious draught of fluid has most water; it is called Urina Potûs.

The quantity of solid excreted by the kidneys in the twenty-four hours is very constant under the same circumstances; it varies from two to three ounces; about half this consists of urea.

The quantity of urea is variable, according to the quantity of nitrogenous food taken. When the weight of the body remains constant, the amount of nitrogen, in the urea excreted, is nearly equal to that in the food taken. When the weight of the body is increasing by growth, less nitrogen is excreted than is taken in, and in wasting diseases more is excreted than is ingested.

The formula of urea is CH_4N_2O, which may be written—

$$N_2 \left\{ \begin{array}{l} H_2 \\ H_2 \\ CO \end{array} \right.$$

This represents a double atom of ammonia with a double *atom of* its hydrogen replaced by the hypothetical radical carbonyl, CO, isomeric* with carbon monoxide.

Urea is isomeric with cyanate of ammonia, and has been prepared artificially. It becomes converted into carbonate of ammonia and water in the presence of decomposing mucus, or any other easily decomposed nitrogenous body.

It is probably formed in the blood by the disintegration of the nitrogenous tissues, and, perhaps in the liver, by the breaking up of nitrogenous food into glycogen and urea. It is at once taken from the blood, by the kidneys, before enough accumulates to have a deleterious effect; the accumulation of urea in the blood gives rise to coma, convulsions and death—uræmic poisoning.

Uric acid only exists in very small quantities in healthy human urine; about eight grains are excreted in the twenty-four hours, chiefly in the form of urates. A larger quantity is excreted when animal food is taken in excess, and in gouty conditions.

Impaired oxidisation of the blood and a plethoric condition increase the quantity of uric acid excreted.

The colouring matter of the urine is allied to that of the blood, from which it is derived; it is called urohæmatin.

The salts of the urine amount to from half an ounce to three quarters of an ounce in the twenty-four hours; they are chiefly phosphates, sulphates, and chlorides.

The phosphates are probably chiefly set free from the tissues by their disintegration, especially from the nervous tissues. The chlorides, principally chloride of sodium, are derived directly from the food; and the sulphates, in part, from the sulphates in the food, but chiefly from the oxidisation of the sulphur of the food and tissues.

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* *Having the same* chemical composition, but different *physical and chemical* characters.

Beside the substances named, urine contains a small quantity of hippuric acid, and traces of nitrogenous extractives intermediate in composition between the proteids and urea.* There is also a small quantity of mucus derived from the bladder.

The specific gravity of urine varies from 1015 to 1025. When the quantity of urine is very small, as in very warm weather, a higher specific gravity does not indicate disease; but a large quantity of urine with a high specific gravity, or a small quantity of urine with a low specific gravity, is indicative of disease.

XIX.—THE SKIN.

The skin consists of the dermis, and of the epidermis and its appendages.

The dermis consists of a dense net-work of connective tissue. The fibres of which it is composed are so closely woven at its outer surface that they can be scarcely distinguished with the microscope; it becomes looser beneath, and passes insensibly into the subcutaneous connective tissue.

The subcutaneous tissue is filled with fat-cells, in a well-nourished body; these consist of cells distended with oil.

Fat serves as a store of nourishment, as a non-conductor of heat, and it forms a soft protective cushion beneath the skin. When the supply of nutriment is insufficient, it is consumed in maintaining the heat and activity of the body.

Subcutaneous fat is absent in the eyelids, the prepuce, the scrotum, and the nymphæ.

The surface of the dermis is raised into papillæ; these are most numerous on the most sensitive parts of the skin.

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* Kreatin, Hypoxanthin, etc.

On the palmar surface of the hand, and on the plantar surface of the foot, they are arranged in rows, which can be seen with the naked eye. On the palm there are as many as from thirty to forty thousand papillæ on a square inch.

They are least numerous on the back of the body.

The epidermis consists of two layers: a deep layer of spheroidal growing cells, and a superficial layer of scale-like hard cells. Both layers consist of many tiers of cells.

The superficial cells of the outer layer are being constantly shed and replaced by others from beneath.

The deep layer is called the Rete Mucosum; its cells are constantly being multiplied, and as they come to the surface they become flattened and hard, forming in their turn the cells of the superficial layer and being ultimately shed.

The true skin, the dermis, is perforated by the ducts of the sweat glands.

A sweat gland consists of a long unbranched tube of delicate membrane; it has a wavy course through the true skin, and forms a glomerulus in the subcutaneous tissue. The tube is filled with glandular epithelium, and is surrounded in its convoluted portion by a close plexus of capillaries.

It has been estimated that there are between two and three million sweat glands on the surface of the human body; but the united area of all their ducts, as they open on the surface, is, probably, not more than eight square inches.

The amount of water which evaporates from the surface of the skin in the twenty-four hours is about two pounds.

As only about one-sixth of this could be evaporated from a surface of only eight square inches, it is supposed that the rest is lost by evaporation through the cuticle.

But the fact has been lost sight of that a large quantity of the fluid secreted by the sweat glands probably at once soaks into the epidermis before it leaves the sweat-duct, which passes in a spiral direction through the upper layers of the cuticle; so that the sweat is probably not only lost by evaporation over the orifice of the duct, but over the whole surface of the skin.

When the sweat evaporates as fast as it is formed, it is called Insensible Perspiration; when it accumulates in drops on the skin, it is called Sweat, or Sensible Perspiration.

The fluid which exudes from the sweat glands contains acetate of ammonia, lactic and butyric acids, and the salts of the blood, in very small quantities.

The glands which secrete the cerumen of the ear are modified sweat glands.

The sebaceous glands of the skin are minute racemose glands, which open into the hair follicles; they excrete oily and extractive matter with a peculiar odour. They serve to keep the skin soft, and to lubricate the hair.

Hair is an epidermal appendage. Each hair has a papilla of the true skin at its base, and consists of a bulb contained in a follicle—the Hair Follicle—and of a shaft.

Both the bulb and shaft consist of modified epidermal cells.

The cells of the bulb are spheroidal; those of the shaft form three layers: a central medullary portion of spheroidal cells, a cortical portion of elongated fibres, and a covering of imbricated epithelial scales.

A hair follicle consists of a pouch in the true skin, and is lined by an involution of the epithelium of the surface: this lining consists of two layers, called the Inner and Outer Root-sheath of the Hair.

The nails consist of modified epidermal cells.

The skin is the sensory organ of touch and common sensation.

It is an excretory organ, and is largely concerned in the regulation of the temperature of the body, the amount of evaporation from its surface being the main factor in the regulation of the internal temperature.

About $\frac{1}{50}$ of the carbonic acid developed in the body is lost by transpiration through the skin.

The skin is also capable of absorbing water during immersion in a bath. The absorption of mercury and other drugs through the skin is undoubted.

XX.—The Lymphatic System.

The lymphatics commence in the interstices of the tissues, which are everywhere lined with exceedingly fine transparent cells. These cells are called Endothelium. They differ from epithelial cells in their extreme thinness, and in being developed from the cells of the middle layer of the blastoderm.

Endothelial cells also line the peritoneal, pleural, and pericardial cavities, which may be regarded as great lymph spaces. These cavities all have lymphatics opening into them by mouths called Stomata, surrounded by endothelial cells.

The lymphatic vessels unite together and form larger and larger trunks, like veins.

All the lymphatics pass through lymphatic glands, which are situated on the main lymphatic trunks; these trunks have three coats, like a small vein: the outer coat forms the capsule of the gland.

The lymphatic which carries lymph to the gland, is called the afferent lymphatic; that which takes it from the gland is called the efferent lymphatic. These vessels are usually connected with a depression in the gland called the Hilus.

The substance of the gland is made up of a spongy network of fibrous tissue, which dips in from the inner surface of the capsule. The spaces between the fibres of this network are comparatively large at the peripheral part of the gland, but get smaller and smaller towards its centre.

The spaces in the network are lined with cells, and have numerous cells in their cavities; these cells are engaged in the elaboration of the lymph.

The afferent vessel pours the lymph into the larger spaces at the periphery of the gland, and the efferent vessel collects it from the small spaces in the centre of the gland. Hence a lymphatic gland may be regarded as a kind of living filter for the lymph.

The suppuration of the glands in pyæmic poisoning, the formation of buboes and of cancerous deposits in glands of this class, show that they stop deleterious substances on their way to the blood-vessels.

The efferent vessels either join the thoracic duct, or contribute to the formation of the lesser thoracic duct, which receives the lymphatics of the right arm and the right side of the head and neck.

XXI.—Vascular Glands.

There are certain glands which apparently stand in the same relation to the general circulation and the blood, which the lymphatic glands hold to the lymphatic circulation and the lymph. The most important of these is the Spleen.

The spleen weighs from five to ten ounces in health; it consists of a tough elastic fibrous capsule, and is entirely surrounded by a peritoneal coat.

The capsule dips into the substance of the spleen with the splenic artery at the hilus of the organ. The splenic vein also leaves the spleen at the hilus.

The whole interior of the spleen is filled with a fibrous elastic sponge-like tissue, formed by trabeculæ sent into it from the capsule. The spaces of this sponge-like tissue are filled with a grumous material of a dark red colour, called Splenic Pulp.

The tortuous splenic artery, after dividing into several branches, enters the spleen at the hilus and divides dichotomously. It is accompanied by processes of the splenic capsule, forming a sheath.

The branches of this artery do not anastomose with each other; but the whole vessel continues to divide into parallel branches, until these terminate in capillaries, which open into a cavernous tissue, regarded by some as dilated veins, with very fine walls, and by others as the lacunæ of the splenic tissue.

From these the splenic veins arise, and ultimately pass out by the hilus as six or more veins, which then unite into a single trunk.

The Malpighian bodies of the spleen bear no resemblance to the structures of the same name in the kidney. They are ovoid capsules filled with cells like white blood cells, they are firmly attached to the external coat of the branches of the splenic artery, chiefly at the angles of bifurcation; they measure about $\frac{1}{25}$ of an inch in diameter.

Their use is not known. They are very similar to the sac-like glands which form Peyer's patches in the intestine.

The splenic pulp consists of cells and nuclei, of degenerated red blood cells, and of granules of all sizes.

Sir J. Paget called the spleen the graveyard of the red, and the birthplace of the white blood corpuscles. It is probable that the former undergo disintegration, and the latter are developed in the spleen.

The spleen becomes considerably enlarged after the digestion of a full meal, and it is probable that the nitrogenous products of digestion undergo considerable modification in the spleen. It also appears to serve as a diverticulum for the blood of the portal vein.

The formative functions of the spleen are apparently *shared by the other* ductless glands: the Thymus, the

Thyroid, and the Supra-renal bodies, as well as by the Red marrow of the cancellous bone.

The supra-renal bodies and thyroid gland consist chiefly of minute vesicles filled with cells and nuclei, and surrounded by a capillary plexus.

The supra-renal bodies have a cortical and medullary portion, and the latter abounds in nerve-cells and fibres, so that it has been described as a nervous ganglion. Their use is unknown; but in Addison's disease the whole skin becomes pigmented, and the supra-renal bodies are the seat of remarkable degeneration and inflammatory changes.

The thymus only exists in the fœtus and early life. It grows rapidly up to the third year, then very slowly, becoming relatively less in proportion to the body up to the age of puberty; it then degenerates into fatty tissue and ultimately disappears. Its follicles form a continuous closed cavity.

The red marrow of the cancellous tissue of bone has similar characters to the pulp of the ductless glands; it is also most abundant in young subjects. It consists of water, protoplasmic cells, and colouring matter allied to hæmoglobin.

The white marrow of the shafts of the long bones consists of 95 per cent. of fat; it is merely a form of adipose tissue.

XXII.—The Nervous System.

The nervous system consists of nerves and nerve-centres.

Nerves are larger or smaller bundles of nerve-fibres, bound together by connective tissue. The fibres are of two kinds, Medullated and Non-medullated; the former are the so-called White Nerve-Fibres, the latter the Grey Nerve-Fibres.

A white nerve-fibre consists of a very delicate tube, the primitive sheath. This contains a sheath of white opaque fatty matter—the white substance of Schwann, in the centre of which there is a transparent protoplasmic fibre—the axis cylinder.

In living nerves the contents of the sheath are homogeneous, the separation of the contents into an axis cylinder and medullary sheath, as the white substance of Schwann is called, occurring immediately after death.

The grey nerve-fibres have no medullary sheath, and appear of a yellowish colour when seen in bundles. They are smaller than the white fibres, and occur in the sympathetic, the olfactory, and auditory nerves, without any admixture of white fibres; a few are found intermixed with the white fibres in the ordinary cerebro spinal nerves.

The nerve-centres consist of white and grey substance. The white substance is composed of nerve-fibres; the grey consists of nerve-corpuscles in a very delicate spongy network called Neuroglia. This is probably a connective tissue, and serves to support and bind together the other elements.

The nerve-corpuscles are cells of very various size and form. The largest are stellate; they all give off fine processes which branch and intercommunicate. The fine branches form a network between the cells.

The cells are described as bipolar or multipolar, according to the number of processes they give off. The nerve-cells are nucleated, but have no cell-wall.

A ganglion is a small nerve-centre; all the nerve-centres, except the cerebrum, the cerebellum and the spinal cord, are often called Ganglia.

The spinal cord is spoken of as a series of united ganglia. Any small group of nerve-cells is a ganglion.

The term is used in no other sense by physiologists. Though surgeons sometimes use the word to signify a small tumour, this meaning has nothing whatever to do with the word in its physiological sense.

The function of nerve-fibres is the conduction of nervous impressions. Those which conduct towards the nerve-centres are called Centripetal Nerves; those which conduct from nerve-centres are called Centrifugal Nerves. It has not been made out that there is any difference of structure between these two kinds of nerves.

A nerve-fibre runs through a nerve without dividing. Its inner extremity is connected with one or more nerve-cells in a nerve-centre; its outer end terminates either in some sensory organ, or on one of the epithelial surfaces of the body if it is a centripetal fibre, and in a muscle, if it is a centrifugal fibre.

It is doubtful whether some centrifugal nerve-fibres terminate in the cells of glands or not.

Centrifugal nerves are also motor nerves; centripetal nerves are sensory nerves. Some centripetal nerve-fibres do not produce a sensation when they are stimulated, but the stimulation is reflected to a motor nerve, as in reflex acts.

Most of the cerebro-spinal nerves consist of mixed, motor and sensory, fibres. The nerves of special sense consist entirely of sensory fibres, and some of the cranial nerves are entirely motor in their functions. (See Cranial Nerves.)

The rate of conduction along a nerve is about thirty mètres a second (about thirty-three yards). It is probable that sensory impressions are conducted faster than motor ones.

The functions of nerve-centres are the origination, transference, and reception of nervous impressions.

XXIII.—The Spinal Cord.

The spinal cord is a nerve-centre in which the grey matter is enclosed by the white and forms the grey cornua seen in transverse sections.

Some of the stellate nerve-cells of the cord have been demonstrated to have one of their processes larger than the others, and this is continuous with a motor nerve. The central terminations of the sensory fibres are not known with certainty; they probably end in the network of fine processes given off by the nerve-cells.

The size and shape of the nerve-cells of the spinal cord and other nerve-centres is very variable. The largest stellate cells appear to be motor cells; that is, they are connected with motor nerves, and probably originate motor impulses.

The spinal cord serves to unite the ordinary spinal nerves with the intercranial centres, and so serves as a conductor of sensory and motor impulses from the periphery of the body to the sensorium, and from the organ of volition to the muscles. (The nerve impulses of volition originate in the cerebral hemispheres.)

The spinal cord is also a reflex centre. A centripetal nerve impulse arrives at the cord, and sets in action some of its motor-cells, and an act results without the intervention of the will or consciousness.

Reflex acts, of which we are conscious, but over which we have no volition, may be performed in this way by the cord.

The reflex action of the spinal cord is proved by cases of injury to the cord in which its connection with the intercranial centres is severed. The movement of the foot during sleep when the sole is lightly touched is an example of spinal reflex action.

Centres in the spinal cord are connected with the acts of micturition, of defæcation, and with the sexual functions.

The posterior roots of the spinal nerves are composed *of sensory, and the* anterior roots of motor fibres.

Each posterior root has a ganglion upon it belonging to the sympathetic nervous system; it is probably concerned in some way in the nutrition of the nerve. For when the nerve is divided, the portion to which the ganglion is attached does not degenerate; the other portion becomes atrophied.

The anterior and posterior roots arise respectively from the anterior and posterior cornua of the grey substance.

The part of the cord which conducts each of the different kinds of nerve impulse is still uncertain; but it may be said that motor impulses are conducted by the antero-lateral white columns, that sensory impulses are chiefly conducted through the grey substance, and that the posterior columns of white matter are in some way connected with the muscular sense, or that they are concerned in balancing the body and in the co-ordination of the muscles—they are found in a degenerated condition in loco-motor ataxy.

Motor impulses are conducted by the same side of the cord as that on which the muscles moved are situated; sensory impulses cross to the opposite side of the cord almost as soon as they enter it.

If one half of the cord is divided transversely, the side of the body on which the cord is divided becomes paralysed below the section, and the other side loses the power of perceiving sensations.

Motor impulses pass over from one side to the other at the decussation of the anterior pyramids of the medulla oblongata, so that all the conducting tracts of the cord decussate before they arrive at the higher intercranial centres: the sensory immediately, the motor in the medulla.

A longitudinal section of a part of the cord, in the middle line from before backward, therefore, divides all the sensory tracts in the divided region, but none of the motor tracts; hence anæsthesia of both sides without paralysis results.

XXIV.—The Medulla Oblongata.

The medulla oblongata is the enlarged upper extremity of the spinal cord.

The anterior pyramids are continuous with the lateral columns of the cord of the opposite side of the body, and with some of the fibres of the anterior columns of their own side. They conduct motor impressions, and contain no grey matter; they are prolonged through the pons to the crura cerebri; their prolongations lie on the under side of the crura, and terminate in the corpora striata, which are supposed to be the great motor ganglia of the brain. In the crura, they are called the motor tracts.

The fibres of the anterior columns of the cord nearly all pass into the lateral and olivary tracts of the medulla on the same side, and pass through a large quantity of grey substance. They are continued through the pons with a number of fibres from the cerebellum and corpora quadrigemina, and form the upper part of the crus of the same side, terminating in the optic thalamus.

The optic thalami are the great sensory ganglia of the base of the brain.

The posterior columns of the cord are joined by numerous fibres from the grey matter of the medulla, and form the inferior peduncles of the cerebellum. They are the restiform tracts.

The grey centres in the medulla surround the central canal, and lie in the floor of the fourth ventricle. The olive is a grey convolute capsule, and there is a large nucleus in the restiform tract.

The grey centres in the medulla preside over all the *phenomena of organic life.* There are cardiac and *respiratory centres,* a centre of deglutition, and a centre for the regulation of the calibre of the blood-vessels—the so-called vaso-motor centre. These are all centres of reflex action.

Grey centres in the medulla also form the origin of all the cranial nerves except the first four pairs.

XXV.—THE CEREBELLUM.

The cerebellum is connected with the rest of the nervous system by three peduncles on each side: the inferior peduncles, which have been already mentioned; the superior peduncles, which connect it with the corpora quadrigemina, and the middle peduncles, which form the transverse fibres of the pons, and unite the two lateral halves of the cerebellum.

Its function appears to be the co-ordination of the various complex muscular acts. If the cerebellum of a bird be removed, the bird becomes ataxic—that is, its movements are disorderly, and are no longer performed in harmony with each other.

XXVI.—THE CORPORA QUADRIGEMINA AND CEREBRUM.

The corpora quadrigemina are the chief origin of the optic nerve; they are the centres of the function of vision.

The cerebrum is the centre of all consciousness and volition, as well as of all the faculties of the intellect.

The two lateral halves are united by the Corpus callosum, which forms its great commissure.

It is probable that the grey substance of the anterior portion of the cerebrum is more intimately related to the motor, and that of the posterior portions to the sensory functions.

The grey substance of the cerebrum forms a continuous layer over the convolutions, and the more complex and defined these are, the larger the surface of grey substance.

The higher nerve-centres have a very powerful influence over the action of the lower ones; thus the spinal cord is much more active as a reflex centre when the influence of the brain is removed from it.

During sleep, if the foot is touched, it will be certainly drawn up; this is a reflex act dependent on the cord. When awake we may not take any notice of the touch; yet the foot will not move if the stimulus is very slight, or we may resist the action of the cord and keep the foot still.

These are examples of passive and active interference with the action of the cord; this power is spoken of as Inhibitory.

The reflex activity of the cord is strongly seen in cases in which it is severed from its connection with the brain, as in fractures of the spine.

Complex acts, as walking and running, and the like, are said to be Automatic; they are initiated by the Will, but are carried on involuntarily by the lower nerve-centres. These acts have, as a rule, to be done many times before they become automatic.

Sleep-walking is an example of a pure automatic act, uncomplicated by volition.

XXVII.—The Cranial Nerves.

The olfactory, optic, and portio mollis of the seventh nerves are nerves of special sense. Their functions will be described under the senses.

The third, fourth, and sixth nerves are the special nerves of the muscles of the eye.

The fifth nerve resembles a spinal nerve in having two roots: a large sensory root, with a sympathetic ganglion upon it—the Gasserian Ganglion—and a small motor root, which joins the inferior maxillary division of the nerve after it has passed through the ganglion.

The portio dura of the seventh (the Facial) is a motor nerve, and supplies all the muscles of expression in the face.

The eighth pair consist of the Glosso-Pharyngeal, the Pneumogastric, and Spinal Accessory nerves.

The glosso-pharyngeal nerve contains a few motor fibres, but is chiefly a sensory nerve ; it is concerned in taste. It is still doubtful what share the gustatory portion of the fifth nerve has in the sense of taste ; the general opinion is that the gustatory division of the fifth is the nerve by which we perceive pleasant tastes. Stimulation of the glosso-pharyngeal is the initial stage of the second part of the act of deglutition ; too strong a stimulation of the terminations of this nerve, as in tickling the fauces, gives rise to vomiting. It is believed by some, perhaps from this fact, that it is the nerve by which we perceive nauseous tastes, such as incite vomiting, or a tendency to it.

The pharyngeal branches of the glosso-pharyngeal are probably the centripetal nerves which incite the pharyngeal muscles to contract in swallowing.

The functions of the pneumogastric are very complex. At its root it is apparently a centripetal nerve only ; but it receives motor fibres from the spinal accessory. These motor fibres run in the pneumogastric, and form the inferior and a portion of the superior laryngeal nerves.

The pneumogastric contains cardiac inhibitory fibres, and centripetal fibres from the lungs and stomach, connected with the reflex acts of respiration, the secretion of the gastric juice, and the movements of the stomach. It is not probable that any motor fibres go to these organs through the pneumogastric.

The pneumogastric also sends fibres to the other abdominal viscera ; but nothing certain is known of their functions, except that injury to the grey nucleus of this nerve gives rise to artificial diabetes, probably by disturbing the function of the liver, and so allowing grape sugar to pass from the Portal to the Hepatic veins.

The spinal accessory nerve consists of two parts. The accessory portion passes into the pneumogastric and supplies the muscles of the larynx, becoming the inferior and part of the superior laryngeal nerves.

The other portion of the spinal accessory supplies the trapezius and sternomastoid muscles. These are brought into play during singing and speaking, and serve to antagonize the expiratory muscles.

According to Bernard, when the spinal accessory of an animal is divided, the act of respiration is not affected, except when the animal runs, when the movements of respiration become embarrassed. The spinal accessory may therefore be regarded as a special nerve concerned in regulating the respiratory movements and the tension and position of the vocal cords in the production of sounds in the larynx. It is therefore intimately connected with speaking and singing.

The ninth or hypoglossal nerve is the special motor nerve of the tongue; hence it shares the function of speech with the accessory. It is also concerned in the movements of mastication and deglutition.

XXVIII.—THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic system of nerves consists chiefly of grey fibres, but a certain number of medullated fibres are intermixed with these.

The ganglia of the sympathetic are:

1. The ganglia of the sympathetic cords on either side of the vertebral column.
2. The great ganglionic plexuses in the thorax and the abdomen, the bronchial and aortic plexus, the solar plexus, the renal plexus and the

hypogastric plexus, all closely connected with the aorta.

3. The vaso-motor plexuses on the great arteries.
4. The ganglia in connection with the fifth, the pneumogastric and glosso-pharyngeal nerves, and the ganglia on the sensory roots of the spinal nerves.
5. And lastly, the ganglionic plexuses of the heart and the walls of the intestine (Meissner's plexus.*)

All these are united to each other by sympathetic nerve-fibres; the whole forms the visceral system of nerves.

The sympathetic system of nerves is intimately related with centres in the spinal cord and medulla oblongata—the vaso-motor centres.

The chief function of this complicated system of nerves and ganglia is undoubtedly the regulation of the amount of blood sent to the different organs at different times.

Division of the sympathetic nerve of a part gives rise to the relaxation of its arteries, and to consequent congestion of its vessels. Stimulation of the sympathetic causes contraction of the corresponding arteries, with paleness and bloodlessness of the parts supplied by the excited nerves.

The dilator fibres of the iris are undoubtedly supplied by fibres from the sympathetic; and the movements of the heart depend on the intrinsic sympathetic ganglia.

It is probable that all the non-striated muscles of the viscera are supplied by this system of nerves. It is therefore frequently called the Nervous System of Organic Life.

It is doubtful whether the sympathetic nerve fibres conduct sensory impressions to the brain through the cord.

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* See page 53.

The painful sensations due to the irregular and violent contraction of the non-striated muscle of the intestine and uterus are attributed to the conduction of centripetal impressions by the sympathetic. The splanchnic nerves are also supposed to contain fibres which conduct centripetal stimulations to the medulla, nd so keep up the inhibitory influence of the pneumoastric on the heart as a reflex phenomenon.

XXIX.—The Senses.

The sense of smell is due to the stimulation of the factory nerve, by the contact of the very minute articles of an odorous substance with the nerve-terminations in the mucous membrane of the superior and part of the middle meatus of the nose.

The olfactory bulb is rather a ganglion than a nerve; it gives off nerve-fibres, which pass through the cribriform plate of the ethmoid bone, and which are distributed to the olfactory portion of the nasal cavities.

The terminations of the nerves are epithelial cells, which have a short rod-like process projecting from their free surface; these are called Olfactory Cells.

The sense of taste is like the sense of smell in being caused by the actual contact of substances with the cells in which the nerves of taste terminate.

Cells ending externally in small rod-like processes are described as the terminations of the nerves of taste; these are fusiform in shape, and are arranged in ovoid bundles around the fungiform and circumvallate papillæ of the tongue.

These groups of cells are called Taste Bulbs.

The close relation between smell and taste is known to all; it is sometimes very difficult to tell whether we smell or taste that which is put into the mouth or held to the nose, and we judge of the sensation rather by knowing where the substance is than by the sensation itself.

The sensations produced by the stimulation of the nerves of the general surface of the skin are very numerous. They are the sensations of touch and of weight or pressure, the sensation of heat and cold, and, if the stimulation is strong, of pain.

It is not known whether these differences are due to the stimulation of one or more sets of nerve-fibres. Some hold that each different feeling arises from the stimulation of a distinct set of nerve-fibres; this is, however, very doubtful.

The power of distinguishing heat and cold may, however, be lost, and yet the sense of touch may remain. The sensation of pain is prevented by anæsthetics before the ordinary sensation of touch is annulled.

The sense of weight is probably in great part due to the condition of the muscles at the time. We judge of weights by moving them, and feeling the exertion which this requires, and we know the position of our limbs: this kind of sensation is believed to be due to the tension of the different muscles, and is spoken of by some as the muscular sense; it is perhaps due to a distinct set of nerves.

The sense of touch is most acute where the papillæ of the skin are most numerous. There are special nerve terminations in some of the papillæ called Touch-Corpuscles.

There are several kinds of touch-corpuscles, called End-Bulbs, Touch-Corpuscles, and Pacinian-Bodies.

They all consist of a bulb formed from the connective tissue of the nerve. The touch-corpuscles and end-bulbs have no definite structure, but consist of a homogeneous bulb.

8

This either contains the axis-cylinder of one or more nerve-fibres in its interior—end-bulb; or, running spirally round it—touch-corpuscle.

The Pacinian-bodies are composed of several concentric capsules, in the centre of which the nerve-fibres terminate. Pacinian-bodies are found at the sides of the fingers and toes; touch-corpuscles and end-bulbs are found in the papillæ of the most sensitive parts of the skin.

The other terminations of sensory nerves in the skin are not precisely known, but it is thought by some that they end in the cells of the rete mucosum; by others, as loops in the papillæ of the true skin.

Very fine nerve-fibres have been traced into the epithelial layer of the cornea.

XXX.—The Eye.

The eye consists of three coats. An external one, forming the capsule of the organ; a middle-vascular pigmented coat—the Choroid; and an internal nervous coat—the Retina.

The external coat consists of the Sclerotic and the Cornea.

The sclerotic is a dense fibrous capsule, surrounding the posterior four-fifths of the eyeball; it closely resembles the tunica albuginea testis in structure.

The cornea is transparent, and incloses the anterior fifth of the eyeball. It is a segment of a sphere, having a radius of a little more than seven-and-a-half millimètres, or nearly one-third of an inch. It consists of a peculiar laminated form of fibrous tissue, having an elastic layer—Descemet's membrane—on its inner surface. A layer of epithelium exists on both its inner and outer surfaces of the cornea.

The epithelium of the external surface is continuous *with the epithelium* of the conjunctiva, and consists of numerous layers of cells; the fibrous tissue of the conjunctiva ends at the edge of the cornea. The epithelium of the inner surface is continuous with that on the iris and the anterior surface of the lens; it consists of a single layer of cells.

Numerous stellate cells are found between the layers of the proper tissue of the cornea; these readily absorb minute solid particles of metallic oxides if they are brought into contact with an abrasion of the epithelial layer, and render the cornea permanently opaque; hence the danger of using lead lotions to the eyes.

The second coat of the eye, the choroid, lines the sclerotic. Its anterior portion forms a circular stop or curtain in front of the lens; this is the iris.

The function of the iris is to regulate the quantity of light which enters the eye, and to render the optical picture more perfect by cutting off the peripheral rays of light.

The choroid consists of two layers: an external vascular, and an internal pigmented layer which contains the capillaries of the choroid.

The external layer contains both arteries and veins; it has the veins, Vasa Vorticosa, outside the arteries. The inner layer consists of connective tissue with a large number of stellate pigment-cells imbedded in it, together with a rich network of capillaries.

Around the crystalline lens the choroid has a non-striated muscle in it—the Ciliary Muscle.

The iris consists of a prolongation of the choroid with a muscular layer on its anterior surface. The muscle-fibres are non-striated, and consist of two sets of fibres—a circular sphincter, and a dilator muscle of radiating fibres. The former contracts, and the latter dilates the pupil; the dilator of the pupil is supplied by the sympathetic, and the sphincter by the third nerve.

The cavity of the eyeball is divided unequally into two parts by the crystalline lens. The anterior part contains the aqueous humour, water with two per cent. of salts and extractives. With the cornea it forms a water-lens.

The crystalline lens is contained in a capsule, and is derived from the epithelium of the surface of the embryo. It is developed at the bottom of a follicle which becomes the anterior portion of the eyeball. It consists of albuminous, ribbon-shaped fibres, with serrated edges, arranged in a radiating manner.

The lens, together with the water-lens before described cause the rays of light to come to a focus on the retina. The lens is altered in form, becoming more convex, when we look at near objects, by the contraction of the ciliary muscle. This is spoken of as Accommodation.

The eyeball, behind the lens, is filled with a very delicate reticulum of fibres, the meshes of which are occupied by a gelatinous substance, like the transparent substance of the umbilical cord—Mucoid Tissue. This is called the Vitreous Humour.

The vitreous is inclosed in a very fine capsule called the Hyaloid Membrane. The hyaloid is often reckoned as the inner layer of the retina.

The retina is an expansion of the optic nerve, with its end organs; it is spread out between the choroid and the vitreous, and extends as far forward as the ciliary muscle.

An imaginary line drawn through the middle of the cornea and crystalline lens is called the Optic Axis. The part of the retina which this line meets is its most sensitive portion; as this part of the retina has a distinct yellow colour, it is called the Yellow Spot. There are several marked peculiarities in this portion of the retina, which are mentioned below.

The optic nerve enters the eyeball about three millimètres to the inner side of the centre of the yellow spot, if we measure from the centre of the optic nerve.

It pierces all the outer layers of the retina, and spreads out in a radiating manner forming the inner surface of the retina. Its fibres do not cross the yellow spot, but diverge and surround it.

The fibres of the optic nerve then dip into the retina and end in a layer of rod-like bodies, on its external surface, which form Jacob's membrane.

The retina between the optic nerve layer and Jacob's membrane consists of a layer of stellate ganglion cells, and of two layers of nuclei separated from each other by granular nervous tissue.

Jacob's membrane consists of a single layer of rod-like bodies; these are the structures which are sensitive to light. These bodies are of two kinds: thick, somewhat conical rods, called Cones, and more slender ones, called Rods.

Jacob's membrane at the yellow spot consists almost entirely of cones; where the optic nerve pierces the retina, both rods and cones are absent. This is the Blind Spot.

Between the retina and the choroid is a layer of flat hexagonal pigment-cells; this is sometimes reckoned as a layer of the choroid, but it is more properly named the Pigment Layer of the retina.

The rods of Jacob's membrane are purple during life, except after exposure to a strong light. Light destroys the purple, but it is again formed by the pigment-layer of the retina.

This change is connected, no doubt, with the stimulation of the nerve. We cannot say that it is the sole cause, as there is no purple in the cones of the yellow spot.

The stimulation of the nerve is probably a very complex phenomenon, as the perception of colour appears to be due to a different form of stimulation to that which gives rise to the sensations of light and dark.

Although we have two eyes, vision is single whenever the images of objects fall upon corresponding portions of the two retinæ: the inner portion of the right retina corresponds with the outer portion of the left, and *vice versâ.*

The fibres of the inner portions of the retinæ cross each other at the commissure of the optic nerves, and run in the same optic tract, with the outer fibres of the retina of the other eye, beyond the commissure; that is, the inner fibres of one retina and the outer fibres of the other, go to the same side of the corpora quadrigemina.

When we look at near objects, the optic axes of the two eyes converge and meet in the object; this is effected by the contraction of the internal recti. When the eyes converge, the ciliary muscles and the pupils contract. All these acts are simultaneously performed through the agency of the third nerve.

When we look at distant objects, the optic axes are parallel, and the ciliary muscles and the sphincter muscles of the pupils relax.

In some persons the length of the eyeball is so great from before backwards, that all distant objects produce a focus in front of the retina; near objects fall on the retina without their accommodating for them. Such persons are said to be short-sighted—Myopic. They cannot converge the optic axes to look at near objects without at the same time contracting the ciliary muscle; hence, in extreme myopia, the eye either becomes more myopic, or convergence does not occur, and an external squint is the result.

Other persons have an eye too short from before backwards, and have to accommodate for distant objects. Such eyes are said to be Hypermetropic. They soon become fatigued; and tend to get an internal squint.

Both short and long (hypermetropic) sight should be corrected with spectacles.

Old people lose the power of accommodating, and hence require glasses; this condition is called Presbyopia.

The optical picture formed on the retina is inverted, the result of a well-known optical law. We see objects in their true position, from the fact that it is not the optical picture which we perceive—our sensation is due to a change in the brain, and this occurs in such a way that we see things in their true position.

We are ignorant of the changes in the nervous system by which sensation is produced—it is therefore useless to speculate on the subject.

There are a number of other important facts connected with vision, but the student must study them in larger manuals; they are not generally required for any but the higher examinations, and they require very careful study and considerable knowledge of the allied sciences for their comprehension.

XXXI.—THE EAR.

The ear consists of three parts: the external, the middle, and the internal ear.

The external ear in many animals is certainly used to collect the waves of sound, and its movements serve to determine the direction from which sounds come. It appears to serve neither of these purposes in man, and must be regarded as a rudimentary structure.

The middle ear consists of the cavity of the Tympanum; this is filled with air, and communicates with the pharynx by the Eustachian tube. It is separated from the external meatus by the Membrana Tympani. This is thrown into vibrations by the waves of sound.

The centre of the membrana tympani is connected with the handle of the malleus; the vibrations of the membrana tympani set the malleus vibrating as a whole, and this ossicle swings upon a ligament by which it is suspended—the Suspensory Ligament of the Malleus.

The internal ear consists of the bony labyrinth, which is excavated in the substance of the petrous part of the temporal bone; it is filled with fluid called Perilymph. It is separated from the middle ear by a bony partition which is perforated by two fenestræ—the Fenestra Rotunda and the Fenestra Ovalis, or the round and oval windows. These openings are closed by thin membranes.

The vibrations of the malleus set the incus and stapes into motion, so that the movements of the centre of the membrana tympani are exactly reproduced by the movements of the foot of the stapes, except that the latter bone moves through a smaller space, and moves more forcibly than the centre of the membrane.

The fenestra ovalis has the foot of the stapes applied to it, and is therefore the spot which receives the impulses of the ossicles.

In this way the stapes taps upon the membrane of the oval fenestra, and the vibrations are communicated to the internal ear.

It is often said that the vibrations of sound are communicated to the round fenestra by the air in the cavity of the tympanum, but this appears to have another function. The fluid in the labyrinth could not possibly vibrate at all if it were entirely inclosed by bone, and the fenestra rotunda affords the necessary space for the vibration of the fluid of the internal ear.

Suspended in the fluid of the osseous labyrinth is the membranous labyrinth. This is of the same shape, but much more slender than the bony labyrinth; like it, it consists of a vestibule and three semicircular canals. It enters also into the cochlea as the slender Canalis Cochleæ.

The largest part of the membranous labyrinth is the vestibule. This is attached to the oval window, and like the rest of the membranous labyrinth it contains a fluid called the Endolymph.

The impulses of sound are therefore conveyed to the endolymph, and so pass to the extremity of the canalis cochleæ. This lies in the perilymph, and terminates in that portion of the perilymph which is not far removed from the fenestra rotunda.

The auditory nerve is distributed to the membranous labyrinth, and terminates in epithelial cells in its interior.

These cells have minute hair-like processes upon them, and it is believed that these are set into vibration by the vibrations of the endolymph, and that the auditory nerve is stimulated by their movement.

The semicircular canals of the labyrinth are supposed to have some function connected with the maintenance of the equilibrium of the body, as in disease or injury to these structures the power of balancing the body is often lost—Menière's disease.

Some think that they assist in determining the direction of sounds; but the evidence is very strong that the direction of sounds cannot be determined except by moving the head, and so determining the manner in which they are heard most distinctly.

The cochlea is believed to have the determination of tone or pitch as its special function.

Helmholtz supposes that the organ of Corti represents a series of strings which are severally set into vibration by notes of a certain pitch. If you open a piano and raise the dampers by putting down the pedal, and then speak into it, you will hear a repetition of the sounds of the voice echoed back from the strings; this is due to the notes of the voice having produced vibrations of those strings which produce the same notes, and of no others. Helmholtz compares the cochlea to such a set of strings, and thinks that certain rods of Corti are set into action by certain sounds, and so stimulate certain nerve-fibres which give rise to special kinds of sensation.

The use of the Tensor and Laxator Tympani is to adjust the tension of the membrana tympani. We hear high notes best with it tight, and low notes with it loose. We tighten it when we expect very loud sounds of low pitch, and so protect the ear from excessive vibrations.

The vibrations of sound are conveyed to the internal ear by the whole surface of the head, as well as the membrana tympani; so that if deafness is due to destruction or injury of the middle ear, sounds can still be heard by putting the sounding body against the teeth, or by resting the head against a sounding-board; but when deafness is due to injury or disease of the internal ear, or nervous system, of course no sounds can be heard by such means.

XXXII.—GENERATION AND DEVELOPMENT.

The Ovum commences as a structureless cell, containing a vesicular nucleus, called the Germinal Vesicle; this contains a minute bright speck, the Germinal Spot.

The ovum is inclosed in a thick transparent envelope, the Chorion, or, as it is more frequently called, the Zona Pellucida.

The ova are developed in the Ovary. This consists of a fibrous spongy network, containing ova in vast numbers.

In the adult human female the ova are found in different stages of development. The more mature ovarian ova are seen near the surface of the ovary, and each is contained in a vesicle called a Graafian Follicle. The ovary contains one or more ripe ova at a time, and these are seen near the surface of the gland, separated from the cavity of the peritoneum only by the thin wall of the Graafian follicle and the peritoneal covering of the ovary:

At the catamenial period, usually a day or two before the appearance of the catamenia, a Graafian Follicle bursts, and an ovum passes into the Fallopian-tube. The follicle then becomes filled with a small blood-clot.

The clot afterwards shrinks and becomes discoloured, and the walls of the follicle thickened and corrugated; they assume a yellow colour.

The degenerated follicle is about half an inch in diameter; it is called a False Corpus Luteum, to distinguish it from the corpus luteum of pregnancy, which is called a True Corpus Luteum.

The false corpus luteum begins to disappear at the end of three weeks, and at the end of two months its place is occupied by a very small scar.

The unimpregnated ovum is discharged with the catamenial flux.

The above series of changes are very much modified by the impregnation of the ovum.

After impregnation, the corpus luteum increases in size for two months, and then remains of its full size until the end of the sixth month, when it is nearly an inch in diameter: at the end of nine months it is still half an inch in diameter, but has lost its yellow colour; it then appears as a stellate cicatrix.

As soon as impregnation has occurred, the mucous lining of the uterus becomes thick, soft, and very vascular; this is, however, only the further development of a condition which occurs at each catamenial period.

The tubular glands increase greatly in length, and pour out a fluid which fills the cavity of the womb, and is retained there by an albuminous plug which is formed in the cervix.

The ovum, during its passage through the Fallopian-tube, obtains a shaggy villous coat—the Fœtal Chorion; and when it enters the uterus, it becomes attached to its wall. The glandular mucous membrane rises up around it, and buries it in its substance.

The thickened mucous membrane is called Decidua Vera, and that part of it which surrounds the ovum is called the Decidua Reflexa.

The ovum itself undergoes the following changes. It divides into a great number of spherules, and forms the mulberry-mass. The liquefaction of the centre of the mulberry-mass forms the vesicle called the Blastoderm; this then divides into the three layers—Epiblast, Mesoblast, and Hypoblast; these changes have been already described.*

A groove then forms in the epiblast along the region which represents the back of the future embryo: this is the Dorsal Groove. It ultimately closes in behind, and forms the Neural Canal—the cavity for the brain and spinal cord. Its epiblast cells become the future brain and spinal cord.

The mesoblast forms the various tissues of the body, and the hypoblast the lining epithelium of the alimentary and respiratory organs.

The growth of the embryo is due to nourishment afforded by the mother. This is at first absorbed by the villi of the fœtal chorion, afterwards by the Placenta.

The whole of the ovum does not become converted into the embryo, but a portion is divided off from the rest, and remains attached to the embryo by a slender pedicle; this is the Yelk Sac; the pedicle is the Vitelline Duct.

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* See page 8.

The yelk sac contains a small amount of nourishment, which is absorbed by the first blood-vessels of the embryo — the Omphalo-Mesenteric arteries and veins.

The Allantois of the embryo is a papilla at first, which grows from the posterior extremity of the rudiment of the intestine. It receives two large vessels from the aorta of the young embryo; it enlarges into the sac of the allantois, and receives the excretion of the Wolffian bodies and kidneys. A portion remains, as the urachus and urinary bladder; the greater part becomes involved in the placenta.

The Wolffian bodies are two large glands which appear before the kidneys; they are afterwards absorbed. Traces of them only remain, the organ of Giraldès, in the male, and the parovarium in the female, They do the work of the kidneys in the primitive embryo.

The allantois conducts two arteries from the aorta to the chorion; those become the umbilical arteries.

The placenta consists of a portion of the allantois, of that part of the chorion with which it comes into contact, of the umbilical arteries and vein, and of the thickened decidua, now called the Decidua Serotina.

The capillaries between the fœtal arteries and veins in the placenta form loops and dip into the great venous sinuses in the wall of the uterus. The maternal blood here bathes the fœtal vessels, but is always separated from the fœtal blood both by the walls of the fœtal vessels and the very thin walls of the uterine blood sinuses.

Interchanges take place between the mother and the child through these walls; oxygen is given to, and carbonic acid is abstracted from, the blood of the fœtus; hence the placenta serves the purpose of a lung to the fœtus.

Nutrient material is also added to the fœtal blood, and excrementitious substances, as urea, are withdrawn from it in the placenta, the opposite changes of course happening to the maternal blood.

The fact that the blood of the fœtus is aërated in the placenta and not in the lungs, causes the fœtal circulation to differ considerably from that of the infant after birth.

The blood leaves the placenta by the umbilical vein in a pure and oxidised condition; it passes through the ductus venosus into the inferior cava. From thence it passes into the right auricle, but instead of going into the right ventricle, it is guided by a valve called the Eustachian valve through the foramen ovale, an opening in the septum of the auricles, into the left auricle. It then passes into the left ventricle by the contraction of the auricle; the ventricle sends it into the aortic arch, from whence it is distributed by the branches of the aortic arch to the head and neck and to the upper extremities.

It is returned from these parts by the superior vena cava into the right auricle, and it passes the stream of blood from the placenta, from which it is separated by the Eustachian valve, without mixing with it, and enters the right ventricle; the right ventricle sends the blood into the pulmonary artery, but this vessel is impervious or nearly impervious beyond its bifurcation, so that the whole or nearly the whole blood-stream passes through the ductus arteriosus into the descending aorta.

The greater part then returns to the placenta, by the Umbilical Arteries, but a portion is sent through the other branches of the abdominal aorta, and returns by the terminal branches of the inferior cava and mixes with the placental blood in the inferior cava.

The changes which take place in the circulation at birth are due to the closure of the umbilical arteries and vein, and the opening of the capillary circulation through the lungs.

The obliteration of the cavity of the ductus arteriosus is effected in a few minutes by the contraction of its walls.

The closure of the ductus venosus and of the foramen ovale takes a considerably longer time; the latter is closed permanently and entirely only after a few weeks; the former becomes impervious very soon after the stream of blood from the placenta is cut off.

The embryo during its development is inclosed in a double sac, which contains the Liquor Amnii; this sac is developed from the outer layer of the blastoderm of the embryo. It is called the Amnion.

The growth of the uterus proceeds with the development and growth of the fœtus. At the end of 280 days the fœtus is normally expelled from the uterus by the contraction of its walls.

After the birth of the child, the placenta becomes detached from the wall of the uterus, by the rupture of the walls of the uterine sinuses; hæmorrhage from the mother is then only prevented by the complete contraction of the walls of the womb.

After childbirth, the walls of the womb undergo degeneration, and the greater part of the muscular fibres is removed, but the uterus never again becomes so small as it was before the first pregnancy.

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